COLD INJURY

Transactions of the Fifth Conference
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Fifth Conference on Cold Injury

THE JOSIAH MACY, JR FOUNDATION CONFERENCE PROGRAM

DURING THE PAST fifteen years the Josiah Macy Jr Foundation has organized more than twenty conference groups each group meeting for at least two days annually over a period of five or more years Each meeting is limited to twenty five participants (members and guests),

stimulation of creativity among the participants The purpose of the publication of the Transactions of the meetings is to share as far as possible the conference process with a larger audience than could participate personally in the discussions

These conferences provide an opportunity for informal give and take among the participants To further this purpose the number of presentations planned for each day is generally restricted to one or two The member or guest selected to give such a presentation is requested not to read a paper but rather to highlight in an informal manner some of the more interesting aspects of his or her research with the expectation that there will be frequent interruptions by participants in the form of questions criticism or comment Such interruptions during the course of a presentation are encouraged and form an essential part of the group interchange

The conference program has always been viewed by the Foundation as an experiment in communication in which there is room for improvement and need for frequent reappraisal Sufficient experience has already been gained to justify the conclusion that this type of conference is an effective way c
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and of overcor
as the result of this experiment that the major obstructions to understanding among scientists lie in the resistance of human attitudes to change *rather than in difficulties of technical comprehension* Less extensive experience with non scientists has indicated that the effectiveness of this type of conference is not limited to groups of scientists but will function in any group meeting where more effective communication

is the primary goal It is also clear that the same conference technique, with minor changes, is readily adapted to small international conferences

The style of publication of the Transactions has aroused considerable interest and some criticism The criticism has been directed primarily to editorial permissiveness which has allowed in the final text, in some instances, too many questions, remarks, or comments which, although perhaps useful during a heated discussion, seem out of context and interrupt the sequence of thought in the printed volume A few have objected to the principle of publishing in this style and would prefer a depersonalized summary without interruptions

The Foundation Staff and the Scientific Editors of these volumes welcome criticism and hope to profit thereby in increasing the usefulness of the Transactions to scientists and students of science in the country and abroad

FRANK FREMONT SMITH, M D
Medical Director

ANIMAL ADAPTATION TO COLD

LAURENCE IRVING
Arctic Health Institute
Anchorage Alaska

FOR THE PAST 10 YEARS I have been engaged in a study of adaptation to cold This work has been carried on at the Arctic Health Research Center and I shall present a resume of it at this time but first perhaps some orientation would be in order

The interior valley of Alaska (see map) through which the Yukon River flows from east to west is bordered on the north by the Brooks Range Although extreme cold occurs in the interior valley occasionally during winter the mean winter temperature is not as low as it is north of the Brooks Range Summer temperatures are often hot in the valley but they are cool north of the Brooks Range There is a very sharp temperature gradient marked in winter but much more marked in summer which passes *just along the line* shown on the map through northern and Arctic Alaska and then extends southward more or less in accordance with northern limit of timber on the continent

Figure 1 illustrates the range of the various climates of the world the Arctic region with its low temperatures which may pass to $-60°C$ or so in wintertime the temperate region where the winter cold may go to $-20°C$ or so and the tropical region in which the unchanging rather warm temperature is the marked characteristic The so called temperate climate which to most people who live there seems extremely intemperate a great part of the time has an annual mean range of temperature of approximately 40°C But the Arctic climates particularly those in the interior of the continents of Asia and America are marked by extraordinary diversity of the winter and summer mean temperatures let alone the extremes

In these two diverse climates various forms of warmblooded animals have become adapted so that they successfully live there For example within Arctic Alaska there are about 30 species of mammals and about 200 species of birds including those which are migratory although only 20 or 30 bird species are permanently resident

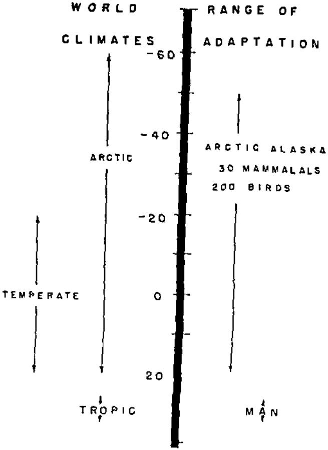

FIGURE 1 The range of temperatures in degrees centigrade encountered in the climates of the world and the range of adaptation of warm blooded animals

To such a wide range of temperatures, various species of birds and mammals are thoroughly adapted But man with his natural physio logic equipment is adapted physiologically to only the very meager range of temperatures such as are characteristically found in the moist or sea level tropical region

Talbott Are all these birds nonmigratory?

Irving No, about 20 or 30 are resident species The remainder of those which I indicated, 180 or so, are migratory

Fremont Smith When you use the word adapted' in this sense, when you say that a man is adapted to only this narrow range, would

you give us a little idea of how you use the word adapted ? What do you mean by it?

Irving By adapted animals and I will go into detail presently, I mean animals that are thoroughly capable as individuals and as popu

Fremont Smith You do not consider that primitive groups who live in these colder areas are adapted in this definition? The Eskimo is not adapted?

Irving I would not think his physiologic adaptation is marked al

lapta

how

many nonhibernators? Do you have any figures?

Irving I think there are only two true hibernating mammals the marmot and the ground squirrel Can you tell us Dr Hock?

Hock That is true north of the Range

Kark Isn t the rate of adaptation of naked aboriginal man a little wider than that? I am thinking of the Australian aborigines who live in quite cold temperatures without clothes or fire

Irving I suppose that is true since according to my definition survival or existence as individuals and populations naked and without much shelter in a climate which frequently is cold in fact near freezing indicates that they must have some adaptation It may be that to some degree the Aleuts also were significantly adapted

Rennie Are not many of the animals exposed to microclimates which are a good deal warmer than the gross temperatures you have indicated? They would not be adapted to such exceedingly cold temperatures

Irving A considerable share of the 30 mammals is composed of the small animals The mice and the shrews we have found to be present in surprisingly large numbers as a sort of basis of the whole carnivorous pyramid of larger mammals in Alaska Those small mammals certainly are not adapted because without the shelter of their burrows and nests they could not possibly withstand the full Arctic cold That is an important reservation

Herrath Dr Irving in these migratory species don t some individuals stay occasionally? Do you consider these as special examples of adaptation within that species?

Irving No although as you say there are a few species of birds in which the majority of the individuals migrate southward and a few

still remain, this situation is rather uncommon There are only a few species of primarily migratory habit among which individuals remain behind during the winter

Horvath Has anyone banded the individuals that stay and studied them over a period of years, to see if they repeat this pattern of remaining behind? Is there some difference between these individuals and the rest of the flock which goes southward? Of those that stay behind have any studies been made which would help in identifying the cause of adaptation?

Irving No, I don t think so The difficulty in all of these studies is the poor discrimination which our physiologic techniques yet allow Often it is very difficult to distinguish the characteristics of an entire population of one species and to differentiate them from another, even when it appears quite different

As for physiologic discrimination of the adaptation or adaptability among individuals within a species, that is an eventual goal

Horvath I would think since there is this individual variation, there might be very striking differences between these, much more than in the over all population

Irving There may well be

Hock I think probably most of these individuals that shouldn t stay and do stay are just committing suicide anyway

Fremont Smith Do they die?

Horvath That is the point do they die?

Hock That is a good question I am not sure

Horvath That is the reason I asked the question—are they banded?

Hock A few occasions of survival through the winter have come to my attention The animals, however, must be in a favorable niche in the environment, a hot spring or some other place where they can get food These places are hard to find and very inaccessible to man Also, only a very few of the individuals do stay when they should not live through the winter If they do there is something wrong with them

Fremont Smith Maybe it is the something wrong with them' from which we can learn Isn t that the point you are making?

Horvath Exactly While it may be pure guesswork as to whether they do survive or come back again, it seems to me that this is a real and logical problem to attack

Burch It has been shown in bird migration that most of the birds that do not migrate do not survive

Horvath Again, it is the problem of whether or not the individual differences that enable some to survive won t give us a lead as to the

adaptive processes that go on or that the whole thing is a matter of chance?

Hildes As Dr Hock indicated these individuals might not be adapted to starvation but they still might be adapted to cold

Hock I had one specific instance and as far as I know it is the only one known When we were at Point Barrow I had a flock of captive snow buntings These normally migrate The last one seen in the wild state was 25 September and at that time the weather was getting quite wintry About 25 October when it was full winter one of them escaped from the cage and I thought Well he is dead The next spring he was retrapped in the same cage at the same spot he had been caught the summer before

Fremont Smith You could identify him?

Hock He was banded This individual had made a migratory flight further south really in the dead of winter when apparently there was little food anywhere for hundreds of miles These birds are seed eaters Of course there were seeds An insectivorous bird could not have done it because there were no insects This bird made it and I think the only reason he made it is the fact that he was able to fly so fast that he got out of the unfavorable environment

Horvath This is an assumption?

Hock I am sure there was no possibility of his lasting there over the winter Not only that but the terrain is just as flat as a table and we could easily have seen anything The Eskimos are astute observers of any unusual phenomenon They certainly would have told us if that bird had been anywhere around there So apparently he was fortunate He made it south and came back next year apparently quite all right Yet he left at least a month perhaps longer after the rest of the population had departed I think he left the area I don t think he stayed

Irving At Anchorage we were discussing the incidence of cold injury among people in the North because we cannot always obtain that evidence Obviously we cannot send questionnaires to the animals we have to do experimentation But we can investigate people by the simple method of asking questions and writing letters So Dr Colyar made some inquiries of the physicians in charge of hospitals in Northern and Arctic Alaska as to the frequency of occurrence of admissions to hospitals for frostbite

In reply to inquiries to three hospitals each one of which served an estimated population of Eskimo people of about 1 000 it was indicated that there were about two or three admissions per year for treatment of frostbite which had occurred A case of extensive disaster or even a local accident such as a plane crash might bring out

a very considerable number of injuries from frostbite in an Arctic community but in general the acute effects of cold are not commonly a major concern in public health even in Arctic Alaska

Talbott You have been studying Eskimos for a long time How many cases have you seen with digit loss?

Irving I haven t noticed any that is I haven t noticed any loss marked enough to make an inquiry about it I don t know what those figures are I do know that the anthropologist Coon (2) feels that the repeated freezing of digits has eventually brought about the shortening of the Eskimo s extremities It was partly because of these statements that we made this inquiry Since the incidence of frostbite is two or three cases per year we can t see that that is a prevalent or a common injury which might be suspected of having an evolutionary influence

However our main purpose in looking into the situation was to find out just what is the magnitude of the frostbite problem in matters of public health

Horvath What is the Eskimo population? These figures have no meaning unless we know

Irving The total Eskimo population in Alaska is of the order of 15 000 or 20 000

Meehan When I was a member of this Laboratory I had occasion to study a number of the Eskimos in the Territory and we did not observe digit loss or as a matter of fact any specific evidence of frostbite injury to the fingers although we saw a number of Eskimos with evidence of frostbite injury to the face

Fremont Smith Were you looking for digit loss?

Meehan As a matter of fact we were doing studies on finger circulation

Fremont Smith So you could have seen it?

Meehan Yes

Rodahl I saw one Eskimo boy who had both hands frostbitten This is the only certain case I know

Irving I am glad to have those comments because I have been very much concerned about this Naturally figures of that sort are important in the establishment of public health policy in Arctic regions The fact that these incidents are rare does not of course remove them from importance to public health where individuals certainly count But it means simply that as a major influence the acute effects of cold injury do not seem to be apparent

We are particularly grateful to the operation of conferences such as this which have brought into proper perspective the very extensive information upon the incidence and characteristics of frostbite in mili

tary personnel for there, unfortunately, frostbite is by no means a matter of minor concern Indeed only from the military can we obtain material for scientific study of the problem of acute cold injury and apply it to civilian considerations

Horvath Is the incidence of frostbite among the non Eskimos greater here?

Irving I don't think there are any figures to indicate that

Horvath Excluding the military

Irving I don t think the figures are sufficient to indicate that It may be, with more comprehensive surveys, that more useful data can be obtained but by and large, the incidence of frostbite or the incidence of deaths from cold, reported in the vital statistics records, from Alaska, are only a few more numerous than, say, throughout the United States at large

Rodahl I would like to add to Dr Irving s remarks Over the last 6 years or so we have had a chance to observe the occurrence of frost injury in certain portions of the population in Alaska Although we have no figures at this time it is our feeling that frost injury is extremely rare in the Eskimo but that it does happen In most cases the injury is in the face and usually it is the result of an accident of some kind Probably the reason Eskimos do not suffer so much frostbite is that they have superior ability in taking care of themselves

Horvath Is it they stay out of the cold?

Rodahl That is partly true because when they are out in the cold they are protected When they don t have any business being outside, they remain in their houses

Kark How about the two who died in the snowstorm? Isn t that unusual?

Rodahl It is one of the few cases where to my knowledge, Eskimos actually froze to death in a snowstorm An old man Timkaro was in camp at Dapok outside Gambell, when he became ill His wife and ten year old son helped him on the sled and started off back to Gambell but they were caught in the snowstorm The man died, however, the mother and the child carried on Later, the mother became exhausted and gave up 16 kilometers from the village but asked the boy to continue alone toward Gambell for help He spent the first night sitting in the snow and by morning his hands were severely frostbitten The next day he happened to meet a man who was attending to his trapline This man brought him to Gambell The mother was eventually found dead in the snow

Montgomery Do you see any instances of frostbite in animals in the Arctic or would that be seen perhaps only in trapped animals?

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Montgomery Do you see any instances of frostbite in animals in the Arctic or would that be seen perhaps only in trapped animals?

Irving Trapped animals, of course, will suffer from freezing Caribou sometimes, particularly the calves, may, in a cold spell, lose their ears or the tips of their ears, from freezing Sled dogs, if forced to work, particularly at the time of the break up, may cut their feet and injure them and then sometimes suffer from local frozen spots on their feet There may also be frost injuries along their flanks, where the harness rubs But I can t think of any instance of an animal apparently in proper health and uninjured suffering from frostbite

Rodahl It does happen that Eskimo sled dogs suffer frostbite occasionally underneath the belly and on the extremities, especially if they are undernourished and in poor condition

Irving Aren t those instances usually a result of the rubbing of the harness or of the dog s being forced to work or being restrained to a local area where he can t seek shelter?

Rodahl In a few cases I have personally observed, this was not the case But the dogs were in a bad nutritional state

Blair Isn t it true that some animals in the Arctic, developing cold injury and not being able to get to warm shelter, will in almost all cases proceed on to hypothermia and death? So perhaps some frost injuries you might see in animals or humans are not alleviated by getting to a warm place, these animals proceed on to a hypothermic death

Hock We see such cases in the captive state The snow buntings I referred to previously were on a wire floor Many of them got a frozen foot condition which was almost invariably fatal Only one survived this condition All the rest of these small birds which got this frozen foot condition invariably died

Normally in the first winter of life bear cubs are with the mother in the den but if kept outside, they show a peculiarity of molting during the first winter They therefore have a practically bare rump and occasionally it is frozen, however, this does not particularly bother them In fact we have a few demonstrations of this in my captive bears now The frostbite is not extensive, but is just a local skin lesion Thus it appears that during the first year of the bear's life if, while he is under captive conditions, he is kept outside he molts and consequently has very light hair covering Hence, he often suffers mild frostbite, because, normally, he is kept in the den with his mother during this period

Fremont Smith Is it fair to say that this is a kind of adaptation by bear cubs which they do not ordinarily exhibit because they are in the den, but when they are taken out of the den, they prove they have adapted to that extent?

Irving Yes, I would say so, they are adapted by their fur and certain physiologic, protective devices

Fremont Smith They molt when they are out in the open and survive perfectly well, with just a little skin lesion

Travell They are physiologically protected

Fremont Smith They call it "adaptation"

Burton This is true of animals in general, not just the bear cub In the first months of life they have the most extraordinary "resistance" Dr Adolph (3,4) has investigated the rat and a great many other animals In their infancy they show this remarkable tolerance to cold

Horvath That applies to dogs also

Hock The difference between the rat and the bear is that the bear at this time is maintaining a normal temperature

Montgomery Would you comment on poikilothermic vertebrates? Are there examples of their survival in the Arctic?

Irving I am afraid the number and the variety is too great for us to go into In Alaska, in the summer or in the spring just as the snow is melting, mosquitoes emerge quite uninjured from the winter

Montgomery I was thinking of vertebrates, amphibia for instance

Irving There are some frogs in Alaska How they exist we don't know, but they do

Blair Do any of the fish actually survive in solidly frozen streams?

Irving There are stories of survival of some fish in frozen ice, but we haven t been able, under experimental conditions either to confirm them or to obtain evidence that looks plausible (5), however, they are interesting stories

Burch Do the mosquitoes and such animals actually have ice crystal in their tissue?

Hock Dr Salt (6) at Lethbridge, Alberta, has done a considerable amount of work on adult insects passing the winter in states of super cooling He has not to my recollection worked on the local mosquito *Culiceta impatiens* which is a large mosquito that hibernates as an adult and in the first warm days of spring not warm because of temperature but because of sun, it emerges According to Salt, other insects survive thus by undercooling, and I assume that this is true for the mosquito also

Fremont Smith What do you mean by undercooling?

Hock Supercooling

Fremont Smith Under and super become equal

Hock I prefer undercooling This mosquito stays still, the temperature drops and he supercools

Fremont Smith Does he freeze?

Hock Apparently he must freeze because the temperature is so low

Fremont Smith He supercools without crystallization

Hock I think that the temperature falls to somewhere below −5°C According to Salt (7) most hibernating insects supercool at least 15°C and crystallization occurs suddenly and rapidly Although heat of crystallization is produced it is rapidly dissipated to the colder surroundings and in a minute or two at the most the supercooling point is again reached

Burch Albert Szent Gyorgyi* is of the opinion that a great deal of water of the body of all animals is in a type of crystalline state It is quite possible that the mosquito may have all of its water so arranged

Hock I should like to add something on so-called hibernation in insects The majority must dehydrate very markedly This apparently is to reduce the dangers of crystallization resulting from excess water This is best known in potato beetles which dehydrate markedly before entering hibernation

Burch They cannot lose all of their water There must be water in some areas

Hock That is known but I have forgotten I think it gets down to approximately 60 per cent

Talbott Are electrolytes lost as well as water?

Hock I don t know

Fremont Smith They must concentrate electrolytes As far as you know they don t seek a little glycerin first?

Hock No that is entirely man made

Montgomery Is it thought that they remain frozen throughout the winter or that they thaw and refreeze and thaw and still come back to life?

Hock That I don t recall

Irving There are certainly many cold blooded animals in which ice does form to a considerable extent as we showed in some measurements made while we were at Point Barrow (5) By actual measurements as much as 40 and 50 per cent of the total amount of water was in the form of ice So that many of the invertebrate cells and tissues and even entire organisms can withstand the actual presence of ice in the tissues and recover from it

Fremont Smith May I refer to Audrey Smith s report at the Fourth Conference on Cold Injury (8)

Irving She has covered that quite well (8)

Horvath Dr Burch s comments about the different forms of water (polymers) should be looked into more This is an old observation

*Personal communication

About 1880 Whiting* was the first to reason there was as much as 10 per cent of the total in the tetrahedral form, which was that of crystal line ice It may be that certain species remove the other kind of water and leave this water intact

Burch One must be careful about the term *supercooling*, especially when comparing a drop of water to the intact cell We do not know very much about the state of the water in cells

Fremont Smith Audrey Smith s study did suggest it (8) because when the animals suddenly froze and became solid (they were hamsters, rats and monkeys) then the temperature came up two or three degrees suddenly

Burch I did not mean these animals, which are different

Fremont Smith You are talking about insects?

Burch Yes

Horvath The question is whether they had been dehydrated, whether this normal kind of water had been removed, and therefore, whether or not they wouldn t have gone into this state without supercooling

Kark Is this crystalline water really exchangeable?

Burch I d[illegible]
state of the [illegible]
the chemicals [illegible]
by him to be [illegible]
which interferes with the passages of electrolytes

Fremont Smith He is talking about mammalian tissues too

Burch Yes

Fremont Smith The old story of bound water too enters into this situation doesn t it?

Horvath There is the implication in the old textbook of physiology by Barnes (9) on these various forms of water That is the only place where it is adequately described In this book Barnes has a very com plete chapter on this problem I think almost everyone has ignored it

Burch The same problem exists for insects living in the desert

Montgomery Is it generally accepted that aqueous solution will freeze at a much lower point if it is in very small quantity? I can re member the statement made years ago that distilled water in a clean glass capillary may freeze at as low temperatures as at $-10°$ or $-20°C$

Burch A drop of water may reduce to a temperature of $-70°C$ if the preparation is proper before it crystallizes

Montgomery Since there is no convection in the fine capillary it might be the same phenomenon

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*Whiting H A new theory of cohesion applied to the thermodynamics of liquids and solids *Thesis Harvard Univ* 1884 (Unpublished)

Hock I think that the temperature falls to somewhere below −5°C According to Salt (7) most hibernating insects supercool at least 15°C and crystallization occurs suddenly and rapidly Although heat of crystallization is produced it is rapidly dissipated to the colder surroundings and in a minute or two at the most the supercooling point is again reached

Burch Albert Szent Gyorgyi* is of the opinion that a great deal of water of the body of all animals is in a type of crystalline state It is quite possible that the mosquito may have all of its water so arranged

Hock I should like to add something on so called hibernation in insects The majority must dehydrate very markedly This apparently is to reduce the dangers of crystallization resulting from excess water This is best known in potato beetles which dehydrate markedly before entering hibernation

Burch They cannot lose all of their water There must be water in some areas

Hock That is known but I have forgotten I think it gets down to approximately 60 per cent

Talbott Are electrolytes lost as well as water?

Hock I don t know

Fremont Smith They must concentrate electrolytes As far as you know they don t seek a little glycerin first?

Hock No that is entirely man made

Montgomery Is it thought that they remain frozen throughout the winter or that they thaw and refreeze and thaw and still come back to life?

Hock That I don t recall

Irving There are certainly many cold blooded animals in which ice does form to a considerable extent as we showed in some measurements made while we were at Point Barrow (5) By actual measurements as much as 40 and 50 per cent of the total amount of water was in the form of ice So that many of the invertebrate cells and tissues and even entire organisms can withstand the actual presence of ice in the tissues and recover from it

Fremont Smith May I refer to Audrey Smith s report at the Fourth Conference on Cold Injury (8)

Irving She has covered that quite well (8)

Horvath Dr Burch s comments about the different forms of water (polymers) should be looked into more This is an old observation

*Personal communication

About 1880 Whiting* was the first to reason there was as much as 10 per cent of the total in the tetrahedral form, which was that of crystalline ice It may be that certain species remove the other kind of water and leave this water intact

Burch One must be careful about the term *supercooling* especially when comparing a drop of water to the intact cell We do not know very much about the state of the water in cells

Fremont Smith Audrey Smith s study did suggest it (8) because when the animals suddenly froze and became solid (they were hamsters rats and monkeys) then the temperature came up two or three degrees suddenly

Burch I did not mean these animals which are different

Fremont Smith You are talking about insects?

Burch Yes

Horvath The question is whether they had been dehydrated whether this normal kind of water had been removed and therefore whether or not they wouldn t have gone into this state without supercooling

Kark Is this crystalline water really exchangeable?

Burch I do not know Szent Gyorgyi considers the physicochemical state of the water in a cell to be important as well as the exchange of the chemicals in the cell The permeability of the cell to ions is thought by him to be related to the shape of the crystalline state of the water which interferes with the passages of electrolytes

Fremont Smith He is talking about mammalian tissues too

Burch Yes

Fremont Smith The old story of bound water too enters into this situation doesn t it?

Horvath There is the implication in the old textbook of physiology by Barnes (9) on these various forms of water That is the only place where it is adequately described In this book Barnes has a very complete chapter on this problem I think almost everyone has ignored it

Burch The same problem exists for insects living in the desert

Montgomery Is it generally accepted that aqueous solution will freeze at a much lower point if it is in very small quantity? I can remember the statement made years ago that distilled water in a clean glass capillary may freeze at as low temperatures as at −10° or −20°C

Burch A drop of water may reduce to a temperature of −70°C if the preparation is proper before it crystallizes

Montgomery Since there is no convection in the fine capillary it might be the same phenomenon

*Whiting H A new theory of cohesion applied to the thermodynamics of liquids and solids *Thesis Harvard Univ* 1884 (Unpublished)

Burch Spatial molecular orientation seems to be related to the phenomenon of supercooling

Montgomery It would be easier to supercool in fine division than in large volume?

Horvath Not necessarily

Fremont Smith What about surface tension? This will play an important role in a capillary tube Might that play a role in this? There is internal pressure there that becomes great, and vapor tension that becomes markedly increased Do you know from the physicochemical point of view whether this would affect freezing point?

Travell Where do the mosquitoes hibernate? Are they completely protected against convection currents?

Hock No one knows that The odd thing is that they come out so early in the spring Presumably they must get under the bark of trees but there are no scaly barked trees in this part of Alaska This type of mosquito has been found elsewhere under the bark of trees That is all I can say

Irving There are many examples which show that Arctic life is quite practical for warm blooded animals They form numerous populations which, by their stability, demonstrate that Arctic existence is certainly not precarious

Taking as an example the Eskimo population of the Arctic, from Greenland to Siberia, the Arctic is populated by Eskimos who form a single ethnic group which we know to have persisted since its first introduction to history by the Norse settlements in Greenland a thousand years ago These people have been the exclusive human occupants of one third of the Arctic circumference for at least one thousand years The Eskimos demonstrate a stability indicating that Arctic life has not been precarious for them as a population

I have camped in many places while traveling in Arctic Alaska and I have seldom failed to find signs that the aboriginal people have also camped in the vicinty One gains the impression that the Arctic has long been populated by people, some of them ancestors of Eskimos, and some of them far more ancient than that Human existence in the Arctic regions, in the form of populations which have stability and persistence has been well established That is a common if somewhat, to us, remarkable fact

I mentioned that in Arctic Alaska there are about 30 species of native wild mammals We have made measurements of the body temperatures in about 20 of those species

Table I shows that there is some evidence for what I say, indicating

TABLE I

Temperature of Arctic and Subarctic Mammals

			Arctic				
28	29	Porcupine	S-A	4 to 13	Shot Captive	20 to −43	37 5 (36 0 to 38 2)
1	1	Pika	S	0 06	Shot	2	39 0
1	1	Musk ox	A			5	40 0
3	3	Mountain goat	S	40 to 140	1 Shot 2 Captive	10 to 20	38 6 (37 8 to 39 0)
8	8	Caribou	A	42 to 120	Shot	−12 to −26	39 0 (38 5 to 40 0)
11	11	Reindeer	A	35 to 110	Shot Captive	15 to −46	38 8 (37 5 to 39 8)

*Values are means and ranges °C mean of 22 species = 38 6° range of means = 37 2° to 40 5°

Reprinted by permission from Irving, L and Krog, J Body temperatures of arctic and subarctic birds and mammals *J Appl Physiol 6, 667 (1954)*

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5	5	Alaska three-toed woodpecker	SR	0 06	Shot	−3 to 8	42 2 (42 0 to 42 5)
3	3	Alaska jay	AR	0 08	Shot	−12	41 0 (41 0 to 41 0)
1	3	American magpie	SR	0 15	Captive	−23 to 7	41 5 (41 0 to 42 6)
1	3	Northern raven	SR	1 2	Captive	−23 to 5	41 3 (40 5 to 42 0)
5	5	Black capped chick adee	SR	0 01	Shot	−11 to −2	40 0 (39 5 to 40 0)
5	5	Alaska pine grosbeak	SR	0 07	Shot	−15 to −2	41 6 (40 0 to 42 7)
2	2	Hoary redpoll	SR	0 012	Shot	−12 to −8	40 5 (40 0 to 41 0)
4	4	White-winged cross bill	AR	0 04	Shot	−12 to −10	41 0 (40 5 to 41 0)
6	8	Eastern snow bunt ing	AR		Captive	−20 to 22	40 0 (39 5 to 41 0)
1	1	Eastern snow bunt ing	SR	0 035	Shot	−2	41 0

*Values are means and ranges °C mean of 30 species of adults = 41 1 range of means = 39 0° to 42 3°

Reprinted by permission from Irving L and Krog J Body temperatures of arctic and subarct c birds and mammals *J Appl Physiol 6 667 (1954)*

just slightly warmer than we found for the Arctic birds There is, however, no distinction to be found between the mean of the species body temperature of mammals and birds in relation to the Arctic climate We think that the slight difference among the species is undoubtedly significant, and perhaps more significant to us is the difference in the mean homeothermous level which has been taken up by the birds and by the mammals a difference there of some three degrees That is a significant difference but the approximate similarity of the warmth of these two classes of warm blooded vertebrates is impressive and important For they were derived from poikilothermic vertebrate ancestry, already quite separated phylogenetically when the ancestral birds and mammals began to appear So there are these two examples of the warm blooded habit settling about homeothermous levels which are very similar but yet significantly different

This suggests to us that there was some precursor or some characteristic of the ancestral vertebrate stock way back before homeothermism began to appear which required the establishment of the two homeothermous class levels at not far different mean body temperatures (12)

Fremont Smith How about marsupials?

Irving They are commonly reported to be somewhat variable in body temperature but as examination of them proceeds further, in their native habitat and somewhat undisturbed, many examples among them show excellent temperature regulation

Fremont Smith Is their mean temperature about the same as that of mammals?

Irving The mean of the measurements which are reported is inclined to be a little lower but in those averages which are reported from Morrison and Ryser quite a number of marsupials have been included perhaps 8 or 10 in the 60 odd measurements, and they do not appreciably change the balance from what is ordinarily thought of as the normal mammalian body temperature

Montgomery Is there any relation between body temperature and body size?

Irving I wouldn t say it is at all apparent

Fremont Smith Mouse and elephant being about the same?

Burton The elephant is 36°C and the mouse is 38° to 40°C

Irving It depends upon the mouse This is interesting but the present data are too scattered I am quoting Morrison on the subject particularly

Horvath Rodbard (13) presented some material showing a relationship between size and body temperature

Irving He said there was a relationship but it wasn t apparent to me

Burton It was a lot better than many biologists thought

Irving I wouldn t say however that it doesn t exist

Montgomery Is there any relation to body size and fluctuation of body temperature around a mean?

Irving There again I don t think the observations are extensive enough to give very much for discussion

Fremont Smith This is worthy of a little further study don t you think Dr Irving?

Irving Very much so but it is a rather difficult subject because it is hard to know whether to look for surface or bulk or the power producing faculty or whatever it might be It would be a very difficult subject on which to obtain conclusive results

I shall give one other example of the indication of the antiquity of some conditions which determine the level of the warm body temperature which the homeothermous animals seem to have elected

One summer in the Brooks Range John Krog and I (14) made measurements of the temperature of the eggs in the nests of Arctic birds during the period of incubation In the nests of seven or eight species we found that the mean temperature during the period of incubation was very close to around 35°C with occasional but surprisingly brief and rare deviations from that temperature

That was rather interesting because the mean temperature among the eggs of birds being incubated in temperate climates has been intensively studied by Kendeigh (15) and Huggins (16) particularly in the vicinity of Cleveland There they find that the mean temperature during incubation is likewise about 35 C So the embryonic development of birds taking place in Arctic nests is actually proceeding at a warm and more or less homeothermous body temperature

It is quite impractical to look at the developmental process which is going on there as having any possibility of recapitulating the development of homeothermism In other words the homeothermous requirement is already implanted in the embryo of birds as it is in the embryos of mammals and their normal development must proceed at the warm blooded level

This is particularly interesting if the incubation of birds in their Arctic nests is regarded as homeothermous type of process there the homeothermism of the incubation is sustained by the behavior of the parent bird which incubates Here is an example in which truly the behavioral regulation of temperature appears in remarkably impressive fashion

Fremont Smith In the marsupial it could be said that the temperature regulation of the emerging embryo is determined not by the parent

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Fremont Smith In the marsupial it could be said that the temperature regulation of the emerging embryo is determined not by the parent

but by the activity of the embryo itself, which climbs actively into the pouch, in contrast to the bird This is an interesting distinction

Hildes How do you make the nest measurements, Dr Irving?

Irving We placed thermocouples in the nests, among the eggs as they were first laid, and then carried the leads a sufficient distance away so that we could approach frequently and make the measurements without disturbing the bird

Fremont Smith These are not internal egg measurements?

Irving No, they were in among the cluster of eggs

Fremont Smith Do you know anything about the internal egg temperature?

Irving I can only feel those might have been, certainly, a little more constant

Fremont Smith Higher from the metabolism of the egg itself?

Irving I think scarcely in the early stages of development In the late stages, metabolism is probably appreciably higher During incubation there probably is a gradual elevation of the actual embryonic temperature So, in that sense, there is some progressive change in their homeothermous level But the point I meant to illustrate by this example, namely, the requirement of the warm blooded nest or of warmth for effective operation of mammalian and avian organisms and tissues is evidently something which is very deeply implanted in the species and presumably represents their carrying along the ancestral substances, reactions, and tissues with all their warm blooded characteristics, just as the four legged mammals carry along the four appendaged, general vertebrate characteristic

Fremont Smith To what extent can the temperature of the egg of any bird, the chickadee, for example, be lowered and then raised again without interfering with the normal, final production of the young? And does this vary in different stages of incubation?

Irving Yes, there is some permissible variation in temperature there, and the amount by which the temperature can be manipulated diminishes progressively as incubation proceeds

Fremont Smith Then doesn t this give some slight evidence of the recapitulation of homeothermism or mightn t this be because these birds are much more poikilothermic in the early stages?

Irving I suppose so When I say it doesn t look like recapitulation, I am again thinking it is necessary to read quite a lot into it, and I am not sure very much benefit can be derived from the speculation nor

can be used to represent a force which is dissipating that heat special case for considering the animal heat machine, Scholander and the rest of us have formulated the situation

$$T_b - T_e = K \times M \times T$$

so that the temperature outside, the temperature of the body minus critical temperature, that is, the temperature at which the animal has increase its metabolism in order to sustain its normal body temperatu s equal to some kind of constant for the terms of measurement, time e metabolic rate and times the insulation, thinking of the insulatio a resistance opposing the dissipation of heat That, of course, is the ne as the empirical heat law of Newton, that a body cools as the rence between its temperature and its surroundings varies Of se, it is in the same form as the empirical laws and statements of Ohm and Fick, and quite a number of others

The principal advantage to us in utilizing this way of viewing animal metabolism is to see that there is a factor which can be considered to represent the resistance to the dissipation of their metabolically produced heat which is their over all insulation, and that insulation varies in a number of different ways

For example, Figure 3 shows in this short model that, if the value of the insulation were 1, then the energy expenditure would increase with the falling air temperature along such a curve as this if the value of the insulation were 2, the slope would be half as great, and 4 would be ne fourth as great, and so on So the various sizes of the insulation can be estimated from the critical temperature and the metabolic rate of the animals

When a number of measurements of the metabolic rates were compared with the air temperature (Figure 4) we found by comparing all of the various animals by putting their normal or basal metabolic rate as equal to 100, this sort of relation among them The polar bear cubs had a critical temperature where the metabolic rate began to rise at about 0°, the small Eskimo dog pup was around −25°C, and extrapolating quite reasonably to the condition for the Arctic white fox, its critical temperature would probably have been of the order of −40°C

In the tropical animals, such as the sloth the raccoon, the monkey, the marmoset, the jungle rat, and the coati the critical temperature appeared to be in the vicinity of 20° to 30°C That is, approximately the temperature of the environment in which they lived, whereas that for the Arctic animals we believe is near the range of the cold temperature to which they are likely to be exposed in the winter

Carlson The fox particularly has a remarkable heat dissipation system

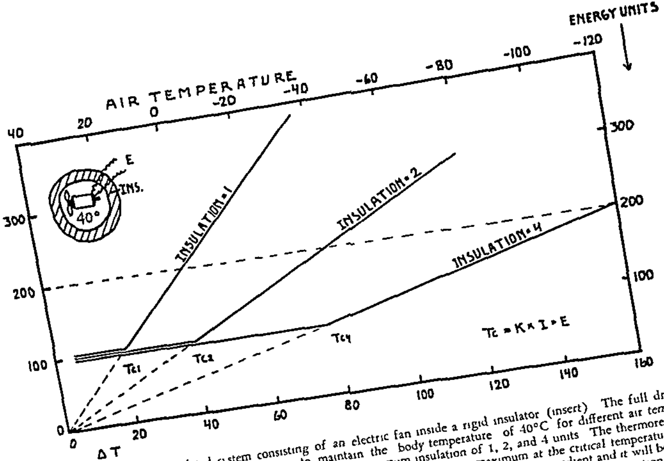


FIGURE 3 A thermoregulated system consisting of an electric fan inside a rigid insulator (insert) The full drawn lines represent the relative energy input necessary to maintain the body temperature of 40°C for different air temperatures, assuming a minimum (basal) energy level of 100 and a maximum insulation of 1, 2, and 4 units The thermoregulation is assumed to proceed in two steps first an increase in insulation until it reaches maximum at the critical temperature, then an increase in the metabolic rate At constant insulation, the system cools proportionally to the gradient and it will be seen from the figure that the critical gradient is proportional to both insulation and metabolic rate according to the equation given Re ...ted by permission, from Scholander, P F, Hock, R J, Walters, V, Johnson, F, and Irving, L Heat regulation in ...ical mammals and birds *Biol Bull* 99, 237 (195

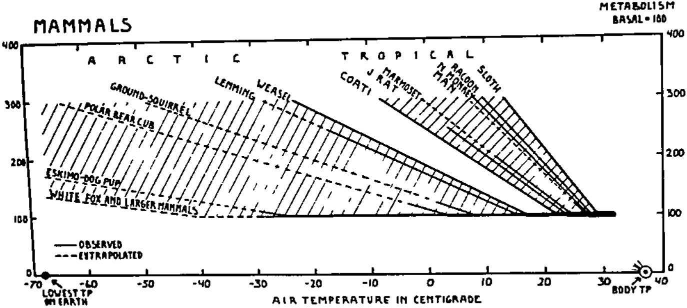


FIGURE 4 Heat regulation and temperature sensitivity in arctic and tropical mammals The fox needs only slight increase in metabolic rate to stand the coldest temperature on earth The critical gradients (tp sensitivity) and the slope of the curves depend on the product of the basal metabolic rate and the over all body insulation Reprinted, by permission, from Scholander, P F, Hock, R J, Walters, V, Johnson, F, and Irving, L Heat regulation in some arctic and tropical mammals and birds *Biol Bull* 99, 237 (1950)

Travell Isn t it true that dogs in general grow two coats of hair? I raised springer spaniels and collies and I have seen them shed their fur in the middle of the fall many times I have often wondered about that without any broad application I think that may be generally true

Meehan Yes it is generally true It is interesting in an animal of this type that he should grow such heavy fur in Los Angeles at a time when the average temperatures are quite high

Montgomery Has the insulation of the two types of fur been studied?

Meehan Not quantitatively

Carlson *Hasn t Hammel (18) measured changes in fur insulation?*

Meehan I don t know he has compared the furs between summer and winter growth

Blair Animals with very heavy fur can protect themselves against a sudden heat stress better than those that do not have such heavy fur We published some work (19) about 15 years ago where we showed that long haired dogs could withstand a sudden heat stress much better than a dog with short hair When we clipped dogs actually their resis tance against heat was decreased (19) instead of being improved We wondered if two factors were not present Long haired dogs had a more effective panting mechanism already conditioned to perform under severe heat stress and the heavy fur is a very effective microenvironment against temperature stress

Meehan That is interesting especially in view of some of the pub lished ideas of Dr Hardy (20) and Dr Hammel who have studied the general thermoregulating mechanisms of various types of animals They have reported that the peripheral vasomotor control of the dog is not as great as it is in the case of the human They believe that the dog has for example some control of the skin blood vessel but not as much as the human This could be in part why the extra insulation on the dog is of value to him particularly in a hot environment

I have made this observation many times in a dog that I have I can take him out on the desert in very warm weather and he will get along very well

Blair After we reported these findings at the Federation Meeting some 15 years ago several friends who had been clipping their dogs during the summer decided they would try not clipping They said their dogs got through the summer heat much better unclipped than clipped

Hildes Dr Irving you have made some observations or reported some recently on pigs and their temperature regulation

Irving I was going to speak about that a little later

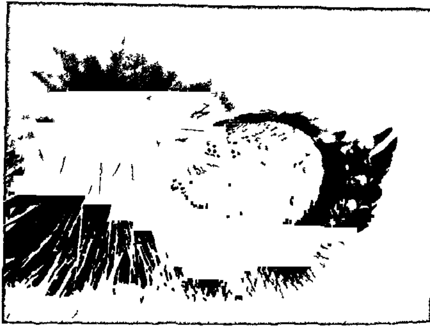


FIGURE 5 Large bare surface of the hindfoot of a porcupine (*Erethizon dorsatus*) Reprinted by permission from Irving L and Krog J Temperature of skin in the arctic as a regulator of heat *J Appl Physiol* 7, 355 (1955)

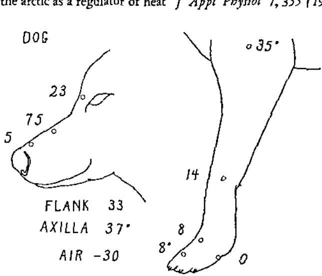


FIGURE 6 Topographic distribution of superficial temperatures in a dog Reprinted by permission from Irving L and Krog J Temperature of skin in the arctic as a regulator of heat *J Appl Physiol* 7, 355 (1955)

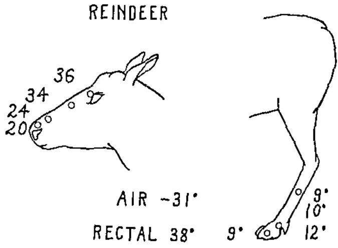
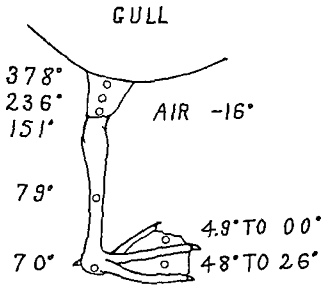


FIGURE 7 Topographic distribution of superficial temperatures in a re ndeer Reprinted by permission from Irving L and Krog J Temperature of skin in the arctic as a regulator of heat *J Appl Physiol* 7, 355 (1955)



FIGU — he leg of a
gull
J
355 (1955)

Irving Every indication points that way I don t see how the tissues can remain viable and sensitive and nourished as they do unless that is the situation

Carlson Scholander told me of a bird, a gull, kept inside most of the winter at Point Barrow When allowed outside, the gull froze to the ice This indicates that the mechanism of controlling circulation comes on gradually as the animal is exposed to cold

Irving That is true In certain cases we know, a developed adaptation, which follows along with the development of cold, is lost when the animal is kept in a warm region That, again, I shall discuss later

Quite different is the situation of the skin on the surface of the body as indicated in Figure 9 which shows some measurements made on the temperature of a sled dog which had been for 3 hours at —50°C in a cold chamber and was then brought out and within a few seconds, at least its skin temperature was measured

At the end of these 3 hours we found that no change had resulted in the body temperature and there was scarcely any change in the subcutaneous temperature in the femoral and tibial region or in the surface of the femoral region where the thick fur covers the body well So in contrast to the extremities, the skin on the body of these well furred

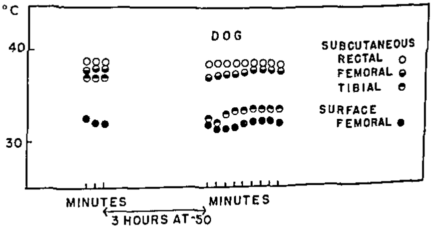


FIGURE 9 Comparison of measurements of rectal subcutaneous and skin temperatures of a quiet arctic sled dog before and immediately after experimental ex

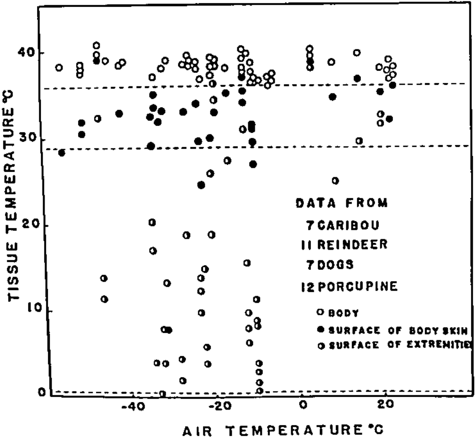


FIGURE 10 Temperatures of body and skin measured in some Alaskan mammals in air at various temperatures Reprinted, by permission from Irving L and Krog J Temperature of skin in the arctic as a regulator of heat *J Appl Physiol* 7,

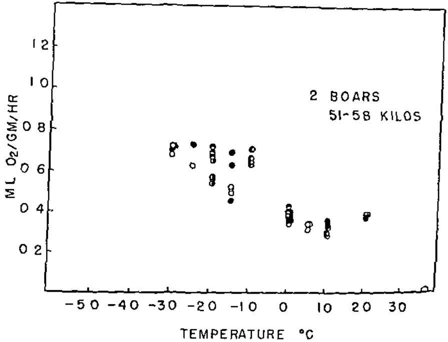


FIGURE 11 Metabolic rates of two young boars Reprinted, by permission from Irving L, Peyton L J and Monson M Metabolism and insulation of swine as bare skinned mammals *J Appl Physiol 9, 421 (1956)*

declines quite regularly until their temperature is around 10° or 12°C, the skin temperature on the body was as low as 10° or 8°C

This we found to be the natural situation in the animals, the larger pigs living freely in the hog house at the experimental farm here at Fairbanks So it looks as if the swine, as bare skinned animals, utilize the flexibility of the surface temperature in the conservation of heat and presumably its warming, for they promptly warm when they become active, as is shown here, for the dissipation of heat, when that is the main issue

We were rather pleased with the appearance of this situation in the swine So, J S Hart (25) and I carried on some observations in the seals first at St Andrews in the wintertime The hair seals of the Atlantic Coast live in winter in water which is nearly at ice temperature, and the range extends along the entire Arctic Coast of America where they live throughout the year, mainly, almost exclusively in fact, in water which is seldom but a few degrees warmer than the ice Their thin hair affords them in air about one tenth the insulative protection

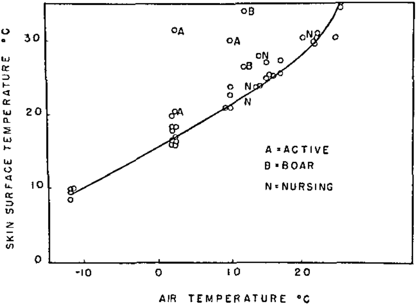


FIGURE 12 Relation of temperatures on surface of swine to temperature of air Reprinted, by permission, from Irving L Physiological insulation of swine as bare skinned mammals *J Appl Physiol 9, 414 (1956)*

of the thick hair on a caribou, but in water it gives them practically no protection whatsoever, because that hair is completely wetted and the surrounding water is not separated from the skin by as much as even a millimeter

Figure 13 shows the critical temperature of several seals in water The small harbor seals which we examined turned out to have a critical temperature, indicated by the line through the solid circles, probably about 10°C In ice water, their metabolism had risen by about 20 per cent

A harp seal which is a strictly northern pelagic form of seal, proved, in the examples which we saw, not to show any increase in its metabolic rate, even in ice water And a very small seal of the same type as a small harbor seal which we called Runt because that is what it proved to be, proved very poor in conservation of heat, for even at 20°C its metabolic rate was near double the normal, and it increased rapidly at lower temperatures than that

Figure 14 begins to suggest some of the reason for the conservational competence of the seals which, living in ice water or living in water,

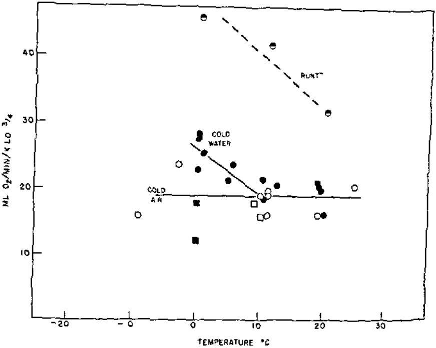


FIGURE 13 Metabolism and critical temperatures of seals
○ = Harbor seals in air
● = Harbor seals in water
□ = Harp seals in air
■ = Harp seals in water
◓ = Runt harbor seal

Reprinted by permission from Irving, L and Hart, J S The metabolism and insulation of seals as bare skinned mammals in cold water *Canad J Zool 35, 497 (1957)*

constantly are exposed to an environment with at least ten times the cooling power of air

The black circles represent the measurements of the temperature on the skin over the body of the seals, while they were in water The declining temperature of the skin is visible, with a decline in the water temperature to 0° The mean of various, numerous temperatures was about 20 degrees warmer than the temperature of the ice water In water at 2°C, the mean difference between skin and water was about one degree

Montgomery Intracutaneous thermocouples, or on the skin?

Irving On the skin surface, by application

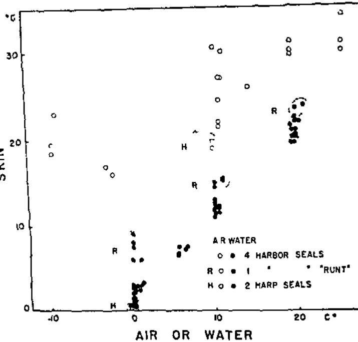


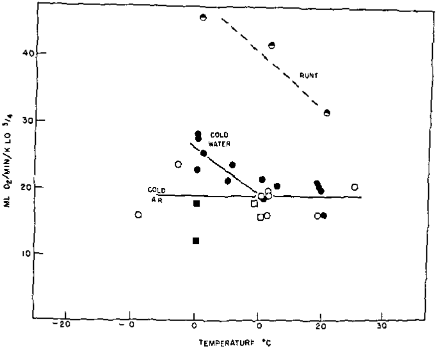
FIGURE 14 Skin temperature of seals Reprinted by permission from Irving L. and Hart J S The metabolism and insulation of seals as bare skinned mammals in cold water *Canad J Zool* 35, 497 (1957)

Montgomery The thermocouple is equally exposed to the surface of the skin and to the water?

Irving It is applied on the end of a small stick which to some degree keeps it from access to the water

The seal which was designated Runt was distinguished from these other seals by its high skin temperature Instead of only 2 degrees or so warmer than the water in ice water Runt s temperature on his body was some 6 or 7 or 8 degrees warmer Even at 20°C it was 4 or 5 degrees warmer

The harp seals which I spoke of as showing no elevation of metabolic rate even in ice water proved to have on the average only half a degree or so warmer skin than the surrounding water We are much inclined to attribute the relation between the difference between water and skin temperature to the heat-conserving abilities of the animals These superficial temperatures on the body of the seals are not alone



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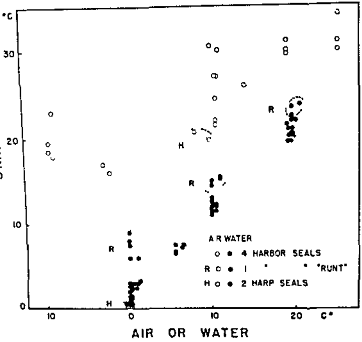

IGURE 14 Skin temperature of seals Reprinted by permission from Irving , and Hart, J S The metabolism and insulation of seals as bare skinned nammals in cold water *Canad J Zool* 35, 497 (1957)

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that of the superficial tissue, for Figure 15 will indicate an example of measurements made through the underlying tissue

Here, when the seal was in water at a little above 10°C, its temperature increased at depths of 5, 10 mm and so on, until at about 35 mm *or so, the body temperature was attained*

In air, at the same temperature, the behavior of this subcutaneous gradient is quite different Here, at the contrasting gradients between air and water at 10°C (this being the behavior of the superficial tissues *when exposed to air) air had only approximately one tenth the cooling* power of water

Figure 16 gives an illustration of the extreme situation in ice water and in warm air at 25°C So the two contrasting gradients of the temperature through the underlying tissues are visible The two lines represent measurements of the gradients which were made at intervals of about 35 minutes, and they represent, probably, variation on the part of the seal rather than on the variability in our measurements, because

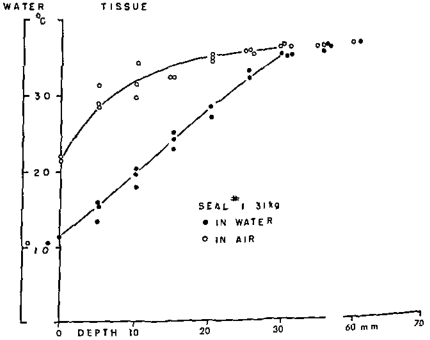


FIGURE 15 Temperature gradient of a seal in air and water *Reprinted, by permission from* Irving L and Hart, J S The metabolism and insulation of seals as bare skinned mammals in cold water *Canad J Zool 35, 497 (1957)*

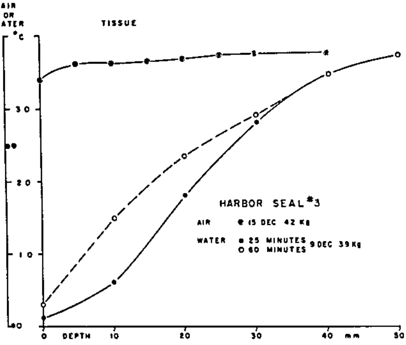


FIGURE 16 Temperature gradient of a seal in warm air and ice water Reprinted, by permission, from Irving L and Hart, J S The metabolism and insulation of seals as bare-skinned mammals in cold water *Canad J Zool* 35, 497 *(1957)*

closely repeated gradient measurements coincided much more closely than do those two lines

This indicates, then, that the change in the superficial temperature

of the maximum attained in the interior of the seal

In these various measurements, the temperature gradient through the superficial 30 to 60 mm of the seal varies both in length and in the difference between body and skin temperature To what extent these two factors are separable, or truly or significantly distinguishable, I do not yet know

Burch By length you mean the thickness of the fat or mean the depth of the fur?

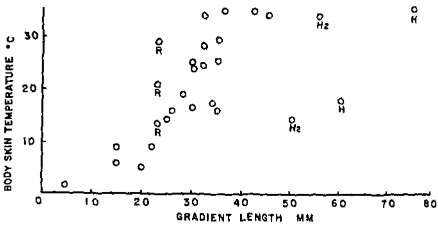


FIGURE 17 Relation between gradient length and skin temperature in harbor and harp (H) seals Reprinted by perm ss on from Irving L and Hart J S The metabolism and insulation of seals as bare skinned mammals in cold water *Canad J Zool* 35 497 (1957)

Irving No the distance from the surface to the point in the interior over which the rising temperature occurred until the temperature got to within half a degree of the temperature of the center of the animal

Montgomery Is most of this distance through fat?

Irving Commonly it is but as is evident there is not much profit in relating that gradient situation to the fat because the fat cannot change its thickness however the gradient can What that means I do not know except that there is no advantage in relating the variability in the gradient to the thickness of the fat

Burch Wouldn t the fur have some insulating effect by trapping air and water between the fibers of the fur so when the animal is in motion the convection would be less?

Irving That may be

Burch Were these animals still?

Irving Yes but the water was circulating slowly so as to keep uniformity in the water temperature about the animal s body Even a millimeter or so of fur is undoubtedly not negligible in its insulative effect but it was so thin that it did not seem practical to attempt to measure it I don t think we could find any variation in a gradient 1 mm long So that although the fur may have some effect I don t see how it can significantly come into the variability

Burch: I wondered if trapping air and water in between the fibers of the fur would tend to maintain a warmer atmosphere next to the skin.

Irving: I am sure there would be some effect but I don't see how it would be possible to make such measurements. I haven't been able to make any, and I can't quite imagine what one can do. For that reason, I am inclined to belittle its importance.

Horvath: Those curves appear to have an exponential nature. Does that simply represent a difference in conduction from the deep to the superficial tissues? They looked very much alike if you plotted on semilog.

Irving: I don't know.

Carlson: It looked to me as though there were two curves on Figure 17.

Irving: You mean on the actual gradient measurements?

Horvath: It looked like two exponential curves.

Irving: Sometimes it did.

Burton: I don't think, if you removed the lines, there would be any justification for having a break.

Irving: Except that we have done further measurements in the summertime. I think there is a break or a change in slope. Actually, I drew them in first as boundaries to contain the actual observations. I wish I had left them out because they imply more knowledge about the situation than I possess.

Fremont-Smith: Dr. Irving, would you say that the fat is not important for the variability but might be important for the total capacity for insulation?

Irving: I am sure it can't be without influence but, as I say, in variable function I think we can perhaps discard the fat because that is the characteristic of the insulator which now appears so important to us.

Rodahl: Is there any difference between a hair seal and fur seal? I understand that in the fur seal the actual skin doesn't get wet as easily.

Irving: I would be very much interested to see what the situation is in the fur seal and the beaver and some of the other animals which apparently live their aquatic life with a dry skin. I would be very much interested to see some measurements to indicate whether they resemble the ordinary, well furred land mammal in keeping their body skin as we do up around 30°C or so.

Montgomery: Does the temperature gradient change when the fur is removed?

Burch: That has been my point.

Carlson Figure 16 gives water temperature, skin temperature, and temperature in the depth

Whaley If the wet skin is only a degree or two warmer than the water under conditions of poor convection, I don't understand why th heat loss should be greater under other circumstances

Behnke The thickness of the fat layer well exceeds the length the gradient, doesn't it?

Irving No, in these seals, which are rather small, the maxim length of the gradient and the thickness of the fat were often com parable But in some individuals we found gradients longer than our measurement of the thickness of the fat, which we haven't been able to make very reliable

Behnke But the gradient did not extend into muscular tissue?

Irving I don't think so Figure 18 may clarify that We have there the measurements of the metabolism of three individual seals, with reference to temperature, showing one of the harp seals with no eleva tion of metabolic rate, one of the harbor seals which rose at probably about 10°C, and the runt seal which was already rising well above the normal basal rate of 20°C

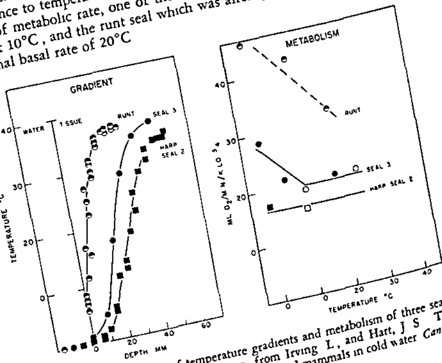


FIGURE 18 Comparison of temperature gradients and metabolism of three seals in ice water Reprinted, by permission, from Irving L, and Hart, J S The metabolism and insulation of seals as bare skinned mammals in cold water *Canad J Zool* 35, 497 (1957)

Here are, in rather compressed form, the insulators, that is, the gradients of these three seals. The characteristic short gradient in the runt seal, which actually was very skinny, is shown. The longer gradient in Seal No. 3 and the longest gradient, which was marked in the harp seal, are also shown.

So, in this sort of qualitative way, it does appear that the conservational ability of this gradient situation varies with the length of the gradient.

Montgomery: Is that necessarily a species difference? Isn't it perhaps wholly a size difference? Would there not be a similar difference between a big harbor seal or a little harbor seal?

Irving: The actual weight of the harp seals that we had was about 40 kg., and the harbor seals averaged around that same weight, too. So the difference between the harp seal and the harbor seal we can't ascribe to size, although the other could be ascribed to size. I am convinced size must have some influence on heat conservation, only that we have no reason for referring to it usefully now.

changes occurred? The difference in fat thickness would then alter the pattern of heat transfer.

Irving: I would think so. Just provisionally, I used a different word and think of the fat as a spacer, but it is the same thing.

as an obstacle to ... ly indicate vari

In looking at Figure 18, I really can't see anything further to say about what the nature of the insulator is because we haven't a picture of the insulator. We just have two of its characteristics in the gradient, and we haven't the essential dimension of local heat flow which would be essential for the definition of the insulator. Whether we could get it or not I don't know. It is a difficult one to try.

Montgomery: A simple question that has not been answered may clarify Dr. Burch's question. Suppose a small patch of fur is taken off one of the fur seals and at a given water temperature, the surface temperature of haired and exposed skins are compared. Perhaps the hair should be pressed down as it is when the seal swims.*

Burch: Was the water moving?

*Much of my experience has been gained in the study of immersion foot in rabbits under a contract between the Office of Naval Research and the University of Pennsylvania.

Montgomery Is there quite a difference between the two tempera tures of the skin, with and without the fur?

Irving That we haven t observed

Montgomery It might be considerable

Irving I have observed the difference in the situation on the back of a seal, when an area of 10 x 20 cm or so emerged above the water and remained there for a few minutes at least, the seal being in ice water That part of its skin and the underlying gradient which we measured corresponded with the general situation in ice water, but that part which emerged from the ice water and was exposed to the air temperature promptly rose in temperature, both at the surface and through the interior So that there is obviously very nice, localizable control of the operation of the superficial temperatures in relation to the heat capacity of the surrounding medium

Burton Dr Irving, I should like to point out one or two pitfalls before leaving this interpretation of the gradients First, suppose you
deciding where the tissue tempera
the final, constant, deep tempera
ner surroundings, you get a total
gradient in the tissues from surface to core' that is less If I have a fixed criterion of one half degree, in which to decide the depth of the gradient, then automatically even though the curves of the gradient, at the two skin temperatures, are the same shape mathematically, I would decide that the constant temperature is reached sooner in the case of the smaller total gradient I would therefore say that the 'depth of the gradient had altered However, if these are mathematically similar curves, the proper criterion to use would be the depth before the temperature is within, say, 5 per cent of the total temperature gradient from skin to core

Then one would find, in this hypothetical case where they are the same shape, that the depth of the gradient was *not* changing So, first of all I want to be precise about what we mean by the depth of the gradient

Irving Do you therefore conclude the length of the gradients does not change?

Burton I don t know I would like to analyze your curves to find out, but I am not satisfied when one takes a fixed criterion, that there is any change in depth of the gradient One should plot, on semilog arithmic paper, the percentage of the total that temperature has yet to change to reach constancy (log scale) vs the depth (linear scale) The curves for different skin temperatures could then be compared directly

The second point on which I am not satisfied, is whether you know that there is a variability of insulation If I were to take a purely physical model with heat generated inside it, and some fixed insulation outside, and I put that first in an environment of 0°, then at 20°C, the surface temperature would rise Not until one has used the device of comparing the ratio of temperature drop from the core to the skin, to the temperature drop from skin to the environment (the 'thermal circulation index') can one know if the insulation has changed For an inanimate object it will not change, although the surface temperature will rise when I put the model in a warmer environment Until you have made the calculation and shown that this ratio (thermal circulation index) changes, I don t know that I can definitely accept a variable insulation If you do, and prove that this ratio changes, then I will begin to think there is a change in the blood flow in the layer of fat

Carlson On the second point, the circulation index, you mean the change is merely one of circulation?

Burton It means this is a measure of the insulation of the tissues over the insulation of the external environment, whether it be the water or the air Only if this ratio changes, do we have to think of a change in insulation of the tissue, which could not occur in a fat layer which didn t have a change in circulation But I don t think you can decide, simply from the fact that when you put the animal in warmer environment, the skin temperature goes up, that this necessarily implies a variability of his insulation

Irving Your objection is good in both cases I have, of course, made these comparisons, but there comes the difficulty of the measurement because the difference in skin and water is at most only about 2 degrees, and the accuracy of our measurements we cannot claim to be much better than one half degree or so So, we have a rather variable dimension, and that is compared, also, with a rather large quantity So the very nature of that ratio as well as our instrumental procedure combine to make that a comparison which I feel is very shaky

Burton It would be a lot better in air than water In air there is a [illegible]

[illegible] I am defending the fact [illegible] cause of the instrumental difficulties and the consideration which has not always been given to the nature of these ratios which, when they become of the order of 1 to 10 or so become, arithmetically, extremely inconclusive

Only if we could keep those ratios about equal can we possibly expect comparison to be significant That, of course, reduces a lot of the physiologic area It is a still inconclusive conclusion that there is a

change in insulation represented there that comes more from the comparison of the three types of seals, in which the three types of gradients are characterized That is more compelling evidence for me than the poor arithmetic I was able to do

Burton I would certainly agree that Figure 19, showing results from the three different seals, indicates definitely a difference in the depth of the gradient in those cases

Montgomery In general, are these seals distributed differently in respect to cold?

Irving Actually the harbor seals which we were working with were obtained from Boothbay Harbor and the harp seals were obtained from the Magdalen Islands There is a considerable difference in the normal environmental temperature of those two

Montgomery So the seal with the higher critical temperature is the one farther from the pole?

Irving We re examined the seals in the summer and found that last summer the same sort of harbor seals had a critical temperature of about 20°C when they were living in the warm water at Woods Hole (Figure 19) So this particular type of insulation, if it be insulation, is treated

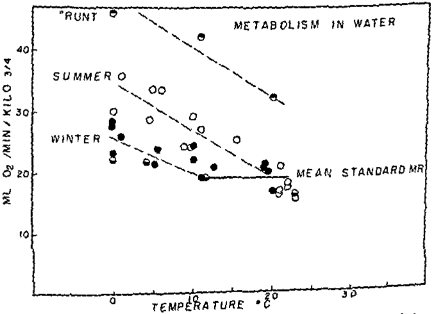


FIGURE 19 Seasonal variation in metabolic response of seals to cold and the aberrant response of the small runt seal From Hart, J S, and Irving L. Unpublished data

biologically like the insulation afforded by fur, namely, the excess is sloughed off in the warm weather, when it is unnecessary That does not give me any explanation

Having reached this situation I can t momentarily see or go any further on experimental grounds but we can look, however, into some of the consequences which appear in the characteristically cool tissues which appear to be an essential part of the adaptation of animals to Arctic life The first I will mention is the change in the characteristics of the substances of the superficial tissues which are shown in Figure 20 This figure shows the melting points of the fats obtained from the bone marrow of the legs of several Arctic animals and from the interior of the animal The marrow fat of a red fox melted at about 38°C, but in the metatarsus the melting point was lower In the wolf we had more extensive measurements The melting point changed from about 38° to 20°C In the dog a corresponding decline in melting point appeared distally along the leg And in another wolf there was a somewhat similar decline But a more marked or better designated decline is shown in Figure 21 in which we compare the melting points of the fat from the reindeer s leg, that is fats taken for convenience of their anatomical designation from the bone marrow They decreased from about 50°C in the femur to about 18°C in the distal part or in the distal phalanges

I thought that was a good example of how nature provides softening of fats of Arctic animals in order that their cold limbs might be flexible until we examined the situation in the leg of a Panamanian brocket deer a tropical deer which is practically indistinguishable in the morphologic distribution of its fat with regard to melting points from the Arctic animal

Fremont Smith That doesn t mean from the evolutionary point of view your original idea may not be correct

Irving In evolution you can say pretty much what you want in almost any company Although I was disappointed by it at first I said that after all this may be the condition which is essential for a type of animal of the deer family to extend its range into an Arctic climate I would say further it would seem very likely that the substantive prop-

many of those substances such as the fats and certain proteins are critically modified by only a few degrees change in temperature and yet they apparently serve the natural purposes quite well at tempera

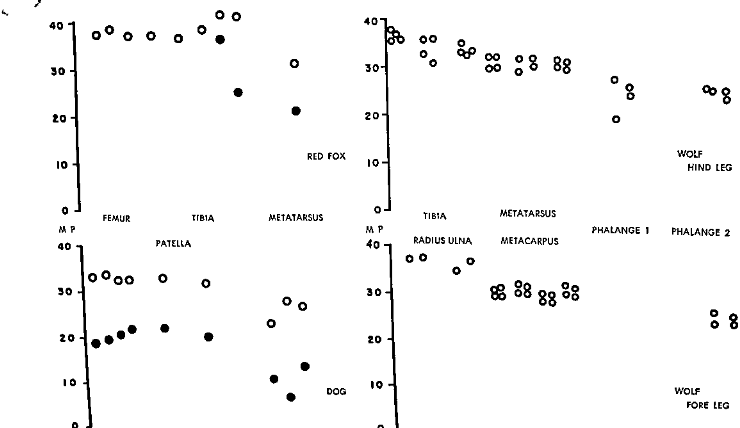
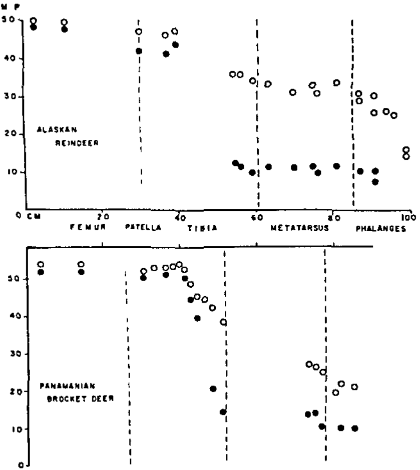


FIGURE 20 Melting temperatures (*open circles*) and temperatures of meniscus formation (*solid circles*) in marrow fats from the bones of three species of arctic carnivores from near Barrow in March Results are shown for duplicate samples from wolf legs Reprinted, by permission, from Irving L, Schmidt Nielsen, K, and Abrahamsen, N S B On the melting points of animal fats in cold climates *Physiol Zool* 30 93 (1957)



tures 30 or so degrees lower So I think there is an interesting type of modification or adaptation to be looked for

Horvath I thought Dill and Forbes (26) showed quite a long time ago that there was a difference in the fat taken at different times of the year

Irving There is

Horvath The pattern may be the same, but the degree of the change is quite different

Behnke Were you comparing deep marrow fat with marrow fat of an extremity, or was that subcutaneous fat?

Irving These were all, for purposes of anatomic localization, marrow fat Soft tissue fat changes in the same way, but it is a little more difficult to designate its source

Behnke Peripheral subcutaneous fat changes in comparison with perirenal fat?

Irving You would get the same comparison I shall mention quickly one other indication of variation or modification which, in very interesting fashion, goes along with the adjustment to Arctic life This is described in the studies which Chatfield, Lyman, and I (27) made on the excitation and conduction in the peripheral part of the peroneal nerve excised from the foot of a sea gull which was adapted to walking around in the cold winter weather of Boston, although Boston is not excessively cold The nerve from the bare metatarsal portion of the gull s leg, which is commonly cold, continued to conduct at a rather low temperature, while the central portion of the same nerve failed to conduct at a temperature 10 to 15 degrees higher, warmer than that

When these gulls were put in strictly warm environment, what we would call adaptation of the nerve to function while cold occurred, disappeared and the peripheral part of the nerve from the limb which was constantly warm had the same properties as the central portion of the nerve

Fremont Smith Does that imply enzyme differences?

Irving I don t know We seized upon this method because of course, the neurophysiologic measurement of excitation and conduction gives us a rather nice quantitative dimension at any rate and serves as what we think is a very useful means for the designation of adaptation of the functional processes which must be taking place in these homeothermous tissues which actually live a heterothermous existence

Many interesting characteristics can be seen from the examination of these cold tissues in which it seems that the heterothermous faculty *is the essence for the preservation of homeothermism* The heterothermous capability of mammalian and avian tissue enables them to live and function over a range of temperature which very few poikilothermous animals can tolerate quickly or even slowly Corals, for example, have existed for the entire evolutionary period *without ever* having been subjected to more than a few degrees difference in temperature Many aquatic poikilotherms have undoubtedly always existed in a range of temperature which is much narrower than the difference which can be

sustained in a so called warm blooded animal as between its peripheral and its central tissues

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18 HAMMEL H T Thermal properties of fur *Am J Physiol* 182, *369 (1955)*

temperature falls to a low level closely approximating the ambient temperature The heart, metabolic, and respiratory rates, as well as other physiologic functions, fall to correspondingly minimal levels It is apparently the minimum state or, let us say, it is the minimum rate at which life may be prolonged The state has been called suspension of vitality, *vie latente*, and *anabiosis* but this is apparently not true There is no suspension of vitality but, rather, a tremendous slowing down of everything

Fremont Smith You say at which life may be prolonged You mean spontaneously?

Hock No The term *vie latente* was used by Claude Bernard, and it means latent life The Russians used the word anabiosis The older workers called it suspended animation which means that life was stopped and could be started up again That is not right

Fremont Smith I did not make myself clear You said hibernation was the lowest temperature at which life can be sustained Isn t it known that body temperature can be artificially lowered and at lower rates sustain life? There is Audrey Smith s work (2)

Hock Yes Perhaps I should say the natural state

Fremont Smith That is what I said, spontaneous meaning natural

Carlson Does it really prolong life? If you prevent hibernation in a laboratory animal does he live a shorter time?

Hock This is a point made by many of the older workers The older workers say if a hibernator is kept from hibernating he will live through that winter but almost invariably die the next summer This is not correct I have had individual ground squirrels captive for over 4 years, some of these have hibernated very well and some have not

Horvath Hibernation always seems such a vague, unsatisfactory word, and it implies that the organism stays in the latent metabolic state for periods of time The question really is what period of time do you mean? Is it a matter of minutes a matter of days months intermittent or continuous?

Hock Months Depending on the climate of the region it may be as long as an 8 month period of hibernation, which is about the longest period known However, they never stay continuously at this low state

Horvath I think that is the important thing, they really don t stay in that state

Hock They stay most of the time

Horvath Do we know they stay?

Hock We know pretty well that they stay in hibernation There is one great difficulty in working with hibernators of course, most hiber

nators in the wintertime are inaccessible except under our captive conditions

Horvath They wake up if you look at them, do they not?

Hock They respond very quickly to stimuli such as a touch or a loud noise and will then awaken However, they also spontaneously awaken because of stimuli which are at present unknown I should like to discuss this in more detail later

Although it had been previously categorically stated that no bird could hibernate, in 1949 a hibernating poorwill, a goatsucker, was found in California (3) However, there is much literature to indicate that birds could and have been found hibernating in the past Studies on hibernation in birds are now being done by several groups (4)

like to describe some other experiments that have been done here in Alaska

There is a tremendous volume of literature on hibernation I have a reference file of 4,000 papers written since Conrad Gesner (5) wrote on this phenomenon in 1551 Although there has been a rather continuous flow of this information, unfortunately, it has never been synthesized, so I shall discuss the work that has been done more locally and tie this in with the main body of information

I am not going to be able to cover all the work that has been done in Alaska, either There now have been about twenty workers in this field, most have been contractors of this Laboratory My own work was started at the Arctic Health Research Center in Anchorage More recently it has been done here Still other work has been done at Point Barrow

A state of hibernation is found in four mammalian orders, the bats, insectivores, carnivores, and rodents These states are not all similar, and I shall try to distinguish between them Among the mammals that do hibernate are the insectivores, in particular the hedgehog of Europe is a very well studied species All bats apparently have a faculty of being able to hibernate, although only those in temperate regions do so

From the 10-kg marmot of Eurasia and Alaska to the 10 gm jumping mouse, more than 20 species of four families have been studied in some

detail The hibernation of ground squirrels, hamsters, dormice, and others is quite well known Until recently, the European hedgehog and marmot, the American woodchuck of the east, and the 13 lined ground squirrel of the midwest were the best studied species of hibernators More recently, the Arctic ground squirrel has become one of the best known species This has occurred in a period of 10 years, because in the fall of 1947 I made an abortive attempt to study hibernation at Point Barrow It was the first study attempted on this species but now, as I say, more than twenty investigators have added to the literature

I shall turn next to a description of body temperature, the reduction of which is the most striking phenomenon of hibernation (6) Figure 22 shows the ambient temperature against the body temperature This

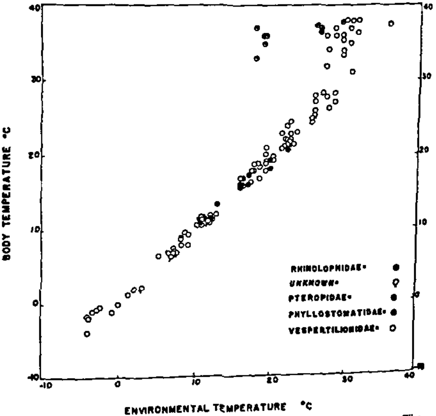

FIGURE 22 Body temperature of bats plotted against ambient temperature The data are collected from all available sources The symbols refer to different families of bats Reprinted, by permission, from Hock R J The metabolic rates and body temperatures of bats *Biol Bull* 101, 289 (1951)

is very close to a 45 degree line until we get up into the region above 30°C, where the animals now have control over their thermoregulatory ability by activity The group shown at 20°C ambient temperature with higher body temperature is alone aberrant These were tropical fruit bats, the most primitive bat They were kept in Oxford zoos and maintained their temperature above ambient temperature by constant activity (7) They clambered around the bars of the cages, moved their wings, and otherwise kept active at all times

This figure indicates that bats have a close correlation between ambient temperature and rectal temperature A bat that has been at 10°C for a long period of time has a temperature of about 10°C This is untrue of the other hibernators as will be shown later, for they have a normal temperature during activity and a low temperature during hibernation Figure 22 shows that some of these bats have body temperatures below 0°C, and most of them recovered from this treatment These are my own data plus all the data I could abstract from the literature They include four families of bats from the tropical fruit bats to the most highly developed insectivorous bats

Carlson Does Figure 22 indicate the extent to which the bat can regulate temperature?

Hock No, I should add that temperature in flight is about 41 5°C The bats can perhaps maintain this when not flying, but only at the expense of great muscular activity

Bats, then, appear to be different from the other mammals or, in fact, the other hibernators They exhibit another phenomenon which has been called

condition in

body temper.

very quickly assuming a temperature equivalent to the room temperature, and perhaps just very slightly higher This happens every day of a bat s life Every time a bat goes out, flies to get his food comes back, and hangs up in the roost, his body temperature drops So, this is apparently an adaptation of the fact that getting food is, for a bat, very expensive because he must fly, and therefore expend a large amount of calories However, I am unable to tell what caloric expenditure is required during flight But this phenomenon I would like to dwell on a bit It is apparent from this that bats are different in their thermoregulatory ability from all other mammals, and it occurs to me that the difference is that the thermoregulatory basis of the bat is not a high constant temperature of 37° or 39°C or whatever it might happen to be, but is ambient temperature

The distinction between bats and poikilotherms is that the bat is able

spontaneously and by activity to raise his temperature above that of the environment, which a poikilotherm cannot do. Instead of having this high and constant and therefore, expensive thermoregulatory level, the bat has one which is geared to the ambient temperature.

Fremont-Smith: It is an altogether different situation from the slight temperature drop we have with sleep. If you said the bat goes to sleep when he hangs up, you could say this drop in temperature toward the ambient is just an exaggerated example of what all of us do in sleep.

Hock: It may be. It is very exaggerated. One time I put a bat with a body temperature of 19.1°C in a vial and placed it in a bath temperature of 1.3°C. In 45 minutes its body temperature was 1.35°C. This illustrates the direct dependence of the bat's temperature on the ambient temperature. Of course, bats have to stay out of ambient temperature below 0°. As a matter of fact, in the caves where they exist, the temperature never gets below 0°. Of course, cave temperature is close to the annual mean temperature of the region. We have the same species of bat I worked on in Ithaca here in Fairbanks but they do not stay here. They apparently migrate to some other place. They stay out of places where they would get below 0° body temperature. This will, I think, be cleared up presently.

Burch: Do bats shiver?

Hock: They have a very violent convulsive shivering during arousal from hibernation.

Burch: When they are dipped in water, do they fail to shiver?

Hock: They were not really dipped in water, but were in vials. However, it is my impression that they did not shiver on exposure to low temperature.

Burch: Why?

Hock: I don't believe they ever shiver when they hang up and start dropping their temperature.

Burch: When they awaken, do they shiver?

Hock: Yes.

EDITOR'S NOTE: Dr. Hock would like to add the following after-thought to his remarks at the Conference:

The fruit bats studied by Burbank and Young (7) did shiver violently when air temperature was 20°C. Note on Figure 22 that they maintained a fairly constant high temperature (33.0° to 37.5°C.) in
air t
that
mec
no a
as a means of warming from low body temperatures.

Fremont Smith This drop in temperature only takes place when they hang up

Hock It can be produced artificially at any time Normally bats shiver when they are about to fly, presumably to raise their temperature You can go into a cave, with bats hanging all over the ceiling, and in about 20 minutes to an hour there will be bats flying in the cave, even though when you first go in they are motionless Soon you can see them start to move their wings

Carlson They warm up before they take off?

Hock Yes, they do In fact, they must warm, they must get to 30°C in this rather painful fashion Then there is a very quick change in temperature, and they can fly in a very short time In fact, they have been found flying at temperatures of about 35°C or so, although the normal flight temperature is about 41° or 41 5°C

Burch If you dip a bat in water, he must try to fly away

Hock This was in a vial in water He was in the air

Burch Why does he not shiver so he could fly away? I do not understand the situation If you awaken a bat in a cave he starts shivering to elevate his body temperature so that he can fly away Still, if you dip a bat in water he does not shiver to keep the body temperature up so that he can make a getaway What is the difference?

Travell You didn t wet the bat?

Hock No, he was in a vial

Burch He certainly was disturbed

Fremont Smith He could have shivered if he wanted to couldn t he?

Hock This is a good question I have never seen one shiver on this reduction in temperature

Burch It is peculiar behavior Most animals would attempt to escape under disturbing circumstances

Hock Perhaps bats are not worried about reduction in temperature, as most animals are

Burch It must not be so simple

Burton The temperature regulation in the hypothalamic center is quite different in a bat It doesn t reflexly respond to cold by defense against cold

Horvath What about the cortical phenomena which have some control over the thalamic areas?

Hock That also would have to be different

Horvath Your data would support that

Behnke It may be that the circulation of the bat s periphery is cut off, and perhaps it is the same in man and when the bat warms up again,

with the blood circulating to the cold area, temperature is reduced, and the animal starts to shiver

Hock It has been shown by Nicoll and others (8) that the wing of a bat is a very vascular area There is little or no blood flowing through the wing under these conditions When the bat s temperature rises above approximately 41°C (9), there is a sudden engorgement of the whole wing of the bat This apparently is a heat loss mechanism The converse is not known, but it appears that as soon as temperature starts to fall there is a shutting off of the wing circulation, so that it almost stops

Hildes The vascularity of the wing doesn't suddenly increase when the bat starts to wake up, does it?

Hock Not until he gets way up to high body temperature It doesn t increase at low temperatures when he is starting to bring his temperature up

Horvath That raises the question of why he shivers at all, if he doesn t when you cool him down in your way What is the missing stimulus? In one case, a minor rise in cave temperature, consequent to entrance by a man, the bat s cortical activity, excited by man s presence, starts him to shiver Yet here, where he is put under much more severe situation, he doesn t shiver, what is the initiating factor?

Hock This awakening shivering is caused by disturbance in the cave, I am sure

Horvath Yes, but still when he is taken from his vial and suddenly dumped into the cold water, he is being disturbed somewhat

Fremont Smith Do they play dead, in that sense?

Hock Not at body temperature of 20°C They are only halfway out of hibernation

Fremont Smith You put them in the experimental conditions where you certainly are disturbing them very much Some animals, under those circumstances, will play dead, so to speak, but do bats do that?

Hock I don t think there is anything that involved in bats

Montgomery Are those at the bottom of the curve in Figure 22 unconscious?

Hock They respond to fairly strong stimuli, if you touch them

Montgomery In waking up he is shivering or is that further up the curve?

Hock They start shivering almost as soon as they start to warm, at very low body temperatures One of the first things they do is to open their wings

Fremont Smith You say, on the one hand, they don t shiver, and

then, on the other hand, you say almost the first thing they do is to shiver

Hock They shiver on awakening but don t shiver on cooling, that is, if you take a bat with a body temperature of 30°C and put him in 0° temperature, he will not shiver

Fremont Smith Then is it fair to say, really, when they are put into this situation they are, in a sense, undisturbed? Otherwise there would be awakening and shivering

Hock No, they are awake They are fully awake When they are put in this zero atmosphere, they drop to zero without shivering

Cotino Could this be because of the fact they are confined, and in the other condition they are free to move about?

[illegible]

and he did that

Burton Isn t it clear that, in the bath, shivering is not part of a temperature regulation or defense against cold? It is not brought out by the stimulus of putting them in cold environment as in the homeo therms, but shivering is elicited by responses to other stimuli, such as disturbing the animal and it exists for the purpose, teleologically, of warming up the animal But it is not a direct response to cold

Fremont Smith A sort of alarm reaction, when they need to do something

Hock This coincides with my idea that the thermoregulatory level is ambient temperature

Blair What is the difference in the rates of fall of temperature? Because whether hypothermia is induced rapidly or gradually makes a profound difference in physiologic response The pattern of development of hypothermia is altered by the speed of reduction of temperature What is the difference in temperatures and the time relationship of the hypothermia?

Hock In general, the more difference there is between the bat s temperature and the air temperature in which he is placed, the faster will be the fall

For example, I placed a bat with an initial temperature of 21 7°C in a vial with a temperature of 23 1 C In 30 minutes his temperature fell to 23 2°C This is a rate of fall of 0 05°C *per minute, in contrast* with the rate of fall of the case mentioned above of 0 4°C per minute As long as this difference is very great, the bat drops—(Table III)

Blair What is the difference in shivering response in those cases?

TABLE III

Temperature Change of Little Brown Bat (*Myotis lucifugus*) in Response to Environmental Temperature

Experimental Temperature		Bat Temperatures		Length of Experiment (min)	Rate of Temperature Change (°C/min)
Water Bath (°C)	Air in Vial (°C)	At Start (°C)	At End (°C)		
1.3	1.3	19.1	13.5	45	−0.39
23.0	23.1	24.7	25.2	30	−0.05
30.2	30.2	36.3	31.2	90	−0.05
37.0	35.5	35.7	37.5	15	+0.11

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Hock: I don't think there is a bit. I have never observed shivering under these conditions.

Burch: What would happen if the bat were dropped in the vial and sort of agitated with the stirring rod?

Hock: He wouldn't drop his temperature.

Burch: He wouldn't? Have you tried such an experiment?

Hock: No, I haven't.

Fremont-Smith: You said when you poke them they do warm up.

Hock: Yes.

Behnke: If the environmental temperature is dropped lower than 0°, then as the body temperature of the bat falls, will he start to shiver? Suppose you lower the temperature?

Fremont-Smith: Does he shiver below 0?

Hock: I think in a very special case he would. I will show you the reason why later in the discussion, because he elevates his metabolism.

Horvath: I think the question is this. If he is at −30°C, let us say, and he keeps on dropping, does he get below this 0° or say −3° or −5°C? How much further below that will he go without responding?

Hock I can t answer that in the case of bats, but I can in the case of ground squirrels

Behnke I ask the question because I am not sure this temperature, as recorded, at all reflects the temperature of the blood, say, reaching the hypothalamus, it may be much lower When blood from the core of the body goes through the cold wings, there is another drop in temperature that is much lower than what you show, and that may be the stimulus that causes shivering At least, in man that can be shown to be the case

Hock These are still temperatures These bats have been in this environment for a while

Behnke What temperature is recorded? Is that a rectal temperature?

Hock Unfortunately, different workers did different things Some took rectal temperatures

Behnke What about your experiments?

Hock I can t pick them out

Behnke What family was used?

Hock They are all the open circles In my experiments I sewed the thermocouple under the skin, using Vernet and Metcalf s (10) method The thermocouple passed around the back of the body of the bat

Behnke You weren t measuring deep body temperature?

Hock No

Horvath That is surface temperature

Hock According to Vernet and Metcalf (10) there is little difference between this temperature and rectal temperature Some of these other temperatures shown are rectal

Burch Rectal temperatures of hibernators have been taken in some experiments at Harvard

Hock That was Lyman s work (11) And those were mostly cheek pouch temperatures of hamsters, not rectal

Burch Yes but he took some rectal temperatures

Hock Yes, in comparison to the cheek pouch temperature He found the cheek pouch warms more on arousal

Burch He studied various parts of the body, as it cooled down

Hock Yes In deep hibernation there is little difference in the heart, liver, or other temperatures especially in the smaller animals They are all at approximately the same temperature in various parts of the body in bats

Montgomery I would be interested to know what happened just below the low environmental temperature that you show Does the curve of the body temperature flatten off or rise, with still lower environmental temperature?

Hock I am afraid no one knows that

Burton Dr Paul Nicoll, who is Professor of Physiology at the University of Indiana, showed me his bats Although everything else seems to be depressed and the animal is torpid, this shivering reflex is on the job, and shivering is a response to cold, once the temperature is below freezing

Hock The bear is the most widely known hibernator Yet bears, as will be shown in Figure 23 do not hibernate Figure 23 is a graph of occasions of measurements The lowest line is outdoor air temperature, the middle line is the den temperature, and the top line is the rectal temperature of the bear (12) It is a little bit difficult to take the rectal temperature of a bear When after about four trials, we finally got rectal temperatures, on almost every first occasion it was 34° or 33 5°C, despite differences in the den temperature The den temperature is really the ambient temperature and it was always below zero The outdoor

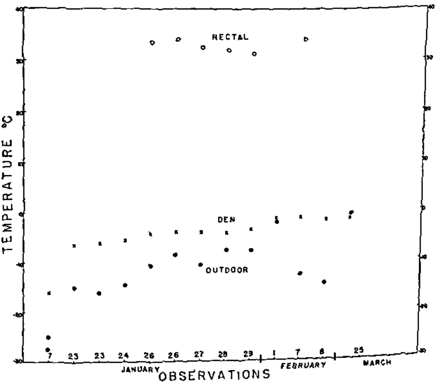


FIGURE 23 Rectal temperatures of hibernating black bears in relation to den and outdoor air temperature plotted by date of observation

temperature might be considerably colder This difference alone shows that the bear is not a true hibernator, because he warms up his den This was of course a fair sized hole in the ground Figure 21 shows a little more detail

Burch How did you get the rectal temperature?

Hock We put a rectal thermocouple in the bear At the time these peratures were recorded no one knew the active temperature of a ar This first measurement was on a black bear (13) It turned out a subsequent search of the literature that there had been three polar ear temperatures recorded between 1820 and 1830 by some of the early Arctic expeditionists (14)

We set about accumulating these bear temperatures Dr Robert Rausch of the Arctic Health Research Center was helpful in getting brown and polar bear temperatures which Irving (15) has already reported Irving has already recorded one of these temperatures from a black bear which he obtained and the three polar bear temperatures were recorded back in the 1800s All active bear temperatures fall around 38°C between 37° and 39°C The polar bears however are a bit different from the other bears in having a more labile body temperature Most of the black bears and the Kodiak brown bears have a temperature near 38°C at all times of the year despite differences in ambient temperature For example there was one shot on December 28 in captivity Even at this time of the year with an air temperature of -30°C it still had a rectal temperature of 38 C In contrast all bear temperatures that have been taken in the dens are much lower than this

One thing that bothered me about these temperatures was the fact we had to disturb the bear In fact we had to get the bear to stand up So this was therefore not a resting temperature On one occasion however I was able to get a thermocouple to stay in place for 3 days There was a drop on each succeeding day until the temperature finally fell to 31 2 C which I feel is perhaps the lowest temperature which the bear normally experiences All of these temperatures are from one bear in the winter In the fall the same bear was pushed out of its den and in 15 or 20 minutes its temperature rose It disturbed me that only one bear was represented as it occurred to me that this might be an aberrant bear So a male bear that had been in the den all winter long was disturbed he walked out of the den and was shot His temperature was immediately taken and was found to be the same as the female's temperature had been when she was first aroused

The temperature of a brown bear was taken by a guide This he felt was the first time this bear had stepped outside Since this graph was made I found another temperature in my records taken on the smallest

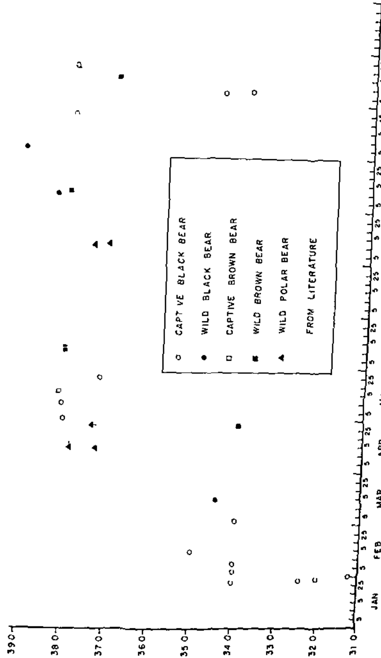


FIGURE 24 Rectal temperatures of active and hibernating black, brown and polar bears *in relation to date of observation*

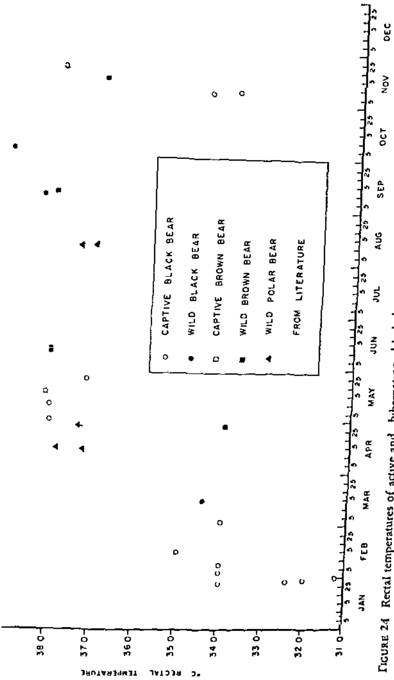
cub I ever had The date was approximately May 15 and the tempera ture was 39°C There are, in addition, three figures in the literature without ambient temperature on the European brown bear They also are between 37° and 38°C Another reading was taken at this Labora tory by Dr Svihla (16), and the other winter black bear temperature is one that Mr Matson has sent me of a wild bear shot in a den They are both very close to my values Thus it appears that there is a real break between active bear temperature and denning bear temperature This break is not very great The bear does not drop its body temperature close to ambient temperature as do the true hibernators It maintains a high body temperature in relation to the low ambient temperature of the winter dens The bear is thus apparently not a true hibernator

studies, but it appears, from the little known, that there is no essential difference between the bear and these other carnivores So, apparently, the carnivores as a group cannot truly hibernate, but some of them have a small reduction in temperature which is perhaps meaningful to them I think they should not be called hibernators in the technical sense I have used

In contrast, Figure 25 shows some ground squirrels Arctic ground squirrels are good hibernators and they fit the definition These are temperatures during hibernation The line shown on this graph repre sents the relationship that would obtain if the animal s temperatures were the same as ambient The figure shows that in most cases it is somewhat higher

It has been stated in the literature many times that rectal temperature is usually two degrees or so above ambient temperature This is obvious ly not always true The figures which show rectal temperature as lower than ambient temperature must be some sort of artifact It may be either that high respiratory water loss is going on, which is unlikely, or that ambient temperatures recently changed and the squirrel s tem perature has not yet had time to rise These squirrels during hiberna tion are reacting not quite but nearly as dead bodies

The temperatures that are very close to the line we can regard as being indicative of hibernation Those that are quite a few degrees above the ambient are apparently those of squirrels in the process of arousal from or entrance into hibernation They are therefore not truly hibernating The ambient is below 0°, and yet the squirrel has main



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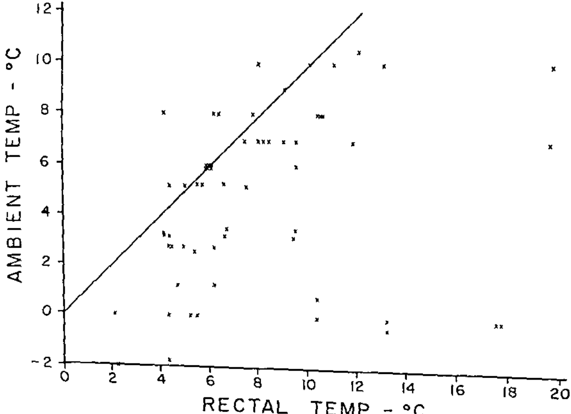

FIGURE 25 Rectal temperatures of Arctic ground squirrels during hibernation in relation to ambient temperature Line indicates where rectal and ambient temperatures are equal Some of these animals are not in deep hibernation

tained temperature above 0° in most cases Only in one or two cases has the squirrel s temperature dropped below 0

Fremont Smith Whether the animals hibernate or do not hibernate is a relative thing They have to come close to ambient temperature to be called hibernators, but there is no real division as to how close You make a sort of arbitrary line and say, This is hibernation If their temperatures don t get that low, it isn t

Hock Yes Contrast this with the picture in the bear where the rectal temperature was way above ambient

Fremont Smith Were any animals halfway in between?

Hock I shall discuss that presently

Fremont Smith This is a spectrum, really, and, when you say it is or is not, you are making a somewhat arbitrary decision

Hock That is right, except true hibernation should be restricted to these cases where it is very close

Fremont Smith How close?

Hock Within a few degrees Hibernators generally have been long stated to have a more labile body temperature during activity because of the fact that they lack true thermoregulatory ability This statement has recently been challenged by Dr Irving (15)

His studies, which were based on some data collected by Erikson at Point Barrow, have since been published by Erikson (17) The thesis of both papers is the fact that the Arctic ground squirrel at Point Barrow has a rather steady body temperature Dr Irving recognized the fact, in one of his statements, that this was not necessarily always true by saying that in September and when not hibernating, these ground squirrels were competent homeotherms

His data were collected during one month of the year I have been able to collect new data (18) from the date of emergence of the ground squirrel, which is 20 April in my study area, to the date of entrance of the ground squirrel into hibernation, which is about 10 to 12 October in the same area

These are animals (Figure 26) that have been shot and their body temperature taken immediately They may or may not have been highly active but such activity does not seem to make much difference They are plotted here as to date The earliest emerging ground squirrels are shown with a fairly constant temperature About the time the females come out there is a greater lability of temperature, in fact it is down to 33°C which is the lowest I have ever recorded As the season goes on, it becomes higher and more constant Usually 20 June is the most perfect time of the year in the mountain area near Anchorage A September group is shown at 40°C This is the time Dr Irving was talking

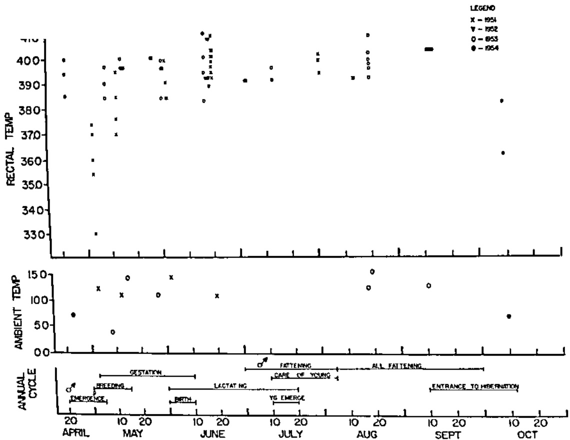

Figure 26 Rectal temperature of Arctic ground squirrels, shot in the wild, in relation to date Below are shown the life history events of the entire season of activity

about Just before the squirrels go into hibernation, there is a marked fall

Kark Will you read the animal s cycle legend?

[illegible] April for the males and the [illegible]

June The young are then in the burrow for about 6 weeks and the females are, of course, lactating About the first of July, the males begin to fatten but at that time the females are still nursing About 10 July, the young emerge and the females care for them for about 10 days to 2 weeks At the end of this time or about 1 August, the females and the young start fattening About 10 September, the females start to hiber nate and the males start somewhere shortly after this About 10 or 12 October, the entire population has gone into hibernation These points bear no resemblance to ambient temperature Also these temperatures are lumped for 4 years and exhibit little difference

Behnke I should like to refer to Figure 25 for a moment For a given rectal temperature, let us say, at 10°C, the ambient temperature varies over a wide range, doesn t it?

Hock The figure shows 10°C

Behnke Yes, that is right, but the ambient temperature, which is plotted along the ordinate, varies over a wide range for a given rectal temperature So, the rectal temperature is independent of the ambient temperature

Hock No, it really is not This chart shows all the figures I had Perhaps I should have selected them Some of these animals are awak ening from hibernation, really 10°C happens to be too high a tempera ture for these ground squirrels This is about the right temperature for the European squirrel

Behnke Let s take 6° or 4°C One can go up over a wide range of ambient temperature and the rectal temperature remains constant

Cotino It is almost up to 8°C in one case

Hock From 0 up to 8°C, that is right

Horvath From −2°C

Burch Have you done a statistical analysis on that?

Hock No

Behnke There is no correlation between the rectal temperature and the ambient temperature

Burton On the contrary I would guess that the coefficient is about 55 That is perhaps not a high correlation but a very definite one

Horvath It doesn t follow that line

Burton It doesn t follow that particular line he has drawn

Hock This line is just a guide to looking at what would be if ambient and rectal were exactly the same Then all the temperatures would fall to this line Obviously they do not

Horvath What you have there is an admixture of animals going down and animals coming up

Hock That is right These were taken from many records These are all levels of activity Perhaps the ones that we should look at are the ones in deep hibernation, but this is a hard thing to judge The best criterion for deep hibernation, as a matter of fact, is if the rectal approximates the ambient

Carlson Has no one used an indwelling rectal thermocouple and followed the temperature during the whole period of hibernation?

Hock No Rectal thermocouples are quite hard to keep in as the ground squirrels are quite active Lyman (19) has made studies on correlation with the cheek pouch temperatures and rectal temperatures and finds that they are closely correlated except during arousal when the anterior portion of the animal warms up quickly and the posterior more slowly

Carlson Both Dr Fremont Smith and Captain Behnke are emphasizing the question as to what a hibernating temperature is

Fremont Smith Also, you say the best evidence you have is that deep hibernation is occurring if the animal s temperature is close to the ambient, but this is also your definition of hibernation So you are using the definition as evidence Unless you have another definition of hibernation, you haven t any evidence of hibernation

Meehan I agree Is there any other criterion on which one could judge the presence or absence of hibernation?

Hock There are many The most convenient one happens to be rectal temperature It takes a very few seconds to determine this

Meehan On the basis of other criteria, could you define rectal temperature that would indicate hibernation?

Hock This depends entirely upon the ambient temperature Most of the time the animal house where I did this was kept between 4° and 6°C Therefore, this group might perhaps be the best one under these particular conditions

Horvath Do these ground squirrels react the same way in hibernation as many other species? May they be in a state of suspension for periods of minutes or perhaps hours then suddenly become active for a while and then return to a state of suspension?

Hock They stay in hibernation up to 3 to 6 weeks Then they spontaneously awaken

Horvath Are they absolutely quiet, without movement?

Hock Yes, apparently so

Horvath It is my own recollection, every time I have gone down to see somebody s animals hibernating, there was a group that was very quiet, another group moving a little bit, and another one moving a little more, yet they were all hibernating

Hock I do not agree with this Out of one hundred captive animals I have had at a time, there might be forty that were in deep hibernation, and there might be twenty that were completely active, and another forty in between, either waking up or going back in To obtain the temperatures shown here, I just went around with a thermometer and started taking temperatures on occasion There is probably a little dis turbance going on because of this and some of the animals have started to arouse already

Fremont Smith Have measurements been made, with a recorder, of activity for individual animals? Such recorders are made

Hock I do not think this has ever been done for hibernators

Horvath It has been done on the hamsters They go into periods of activity, even though they apparently are completely in deep hibernation

Fremont Smith How often would they go into periods of deep hibernation?

Horvath I have found no pattern, nor has anyone else recorded one The animals may be quiet for days or they may go into cyclic activity of very short duration and have a long period of quiescence

Hock As Lyman (20) pointed out hamsters have a shorter cycle than do other hibernators, because they store food According to his results, about every week they arouse themselves and eat These other hibernators that store fat on their bodies, like the ground squirrel and marmot, stay in deep hibernation for longer periods of time

Horvath Benedict s (21) early work on the marmot gave periods of time sometimes as short as a few hours, sometimes as long as a couple of days of hibernation

Hock As long as a month

Horvath What is true hibernation? Periods of activity interspersed with periods of quiescence? Is that hibernation?

Hock Everyone who has ever kept captive hibernators has found this periodic awakening over a fairly long cycle, the cycle differing with different species and also differing, apparently, with different individ uals My own data on these ground squirrels indicate the maximum period of time they do not fully awaken and eat Usually the animals eat lettuce which we kept in front of them as an indicator of their activity They awakened, perhaps at 6 week intervals, in one case and

more commonly at about 3 week intervals The function of this is unknown

The animal whose hibernating temperature we will say is 2°C (Figure 27), when he arouses will have a near normal temperature of say 35°C This may occur in a period of 5 days or 3 hours, it makes no difference The amount of energy that is required to bring his temperature from the point of deep hibernation to the point of activity is enough to sustain him in deep hibernation for at least one month I think Kayser (22) in France has actually worked out the energy required for this transition and finds it is a liability to the animal involved

Fremont Smith So the lettuce doesn t really help him

Hock It doesn t do anything

Horvath He goes back into hibernation, you haven t given him anything to eat?

Hock Hamsters physically store food and they do not store fat So hamsters must apparently awaken at fairly frequent intervals about a week or so, and eat something in order to live It is obvious that it is of benefit to the hamster it is not of benefit to the ground squirrels, because they apparently do not eat, or at least do not eat much They do not store much food

Fremont Smith Wouldn t it be helpful to have some continuous

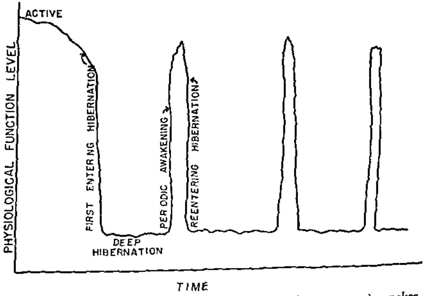

FIGURE 27 Concept of the time course of hibernation showing periodic awakening Physiologic function level might refer to for example, rectal temperature

records of individual animals? It seems to me the lettuce is not a good indicator as to whether or not they have been up and about

Cotino Morrison (23) used the heart rate as a criterion and found that, if you take the heart rate over a long period of time, it will fluctuate between 2 and 15 to 20 beats a minute It is completely irregular

Horvath Are these animals in a continuous state of hibernation?

Cotino He is using the heart rate as the criterion

Kark What happens to the water metabolism? Do they urinate? Is that why they wake up?

Hock To the best of my knowledge they do not urinate However, if you examine them during hibernation and when they have had access to food and water, they do have urine and feces in them

to the so-called state of hibernation

Montgomery Water is offered them?

Horvath It always is in an experimental situation I do not know whether or not it is available in natural states Certainly, experimentally, if water is available to them, they do not necessarily drink it

Fremont Smith What animal are you speaking of?

Horvath Hamsters, ground squirrels and some other animal I cannot remember

Hock In the natural state, these animals do not drink as they have no water available to them I once found this quite puzzling, but in the natural state the animal is in a nest in the burrow, the burrow is underground and the animal is inside Presumably he is not only getting water from metabolism but he is not losing much water by evaporation into the walls of the den, as the humidity of this small chamber must be near saturation

Montgomery It would not be difficult to make a spring suspended case to record not only activity but heart rate continuously

Cotino Morrison (23) has recorded heart rate

Burch Lyman (19) has made such an observation

Horvath The basic question remains what is hibernation?

Hock What you are all saying is that hibernation is not a steady state, but is cyclic It is not a continuous steady phenomenon wherein nothing changes This latter concept was very common in the past among the investigators of the phenomenon As I said previously, the hibernators do arouse Perhaps others have simply not recognized this

fact or they were disturbed because they were not getting a steady state and failed to mention it

Horvath You have made a valuable contribution to the field of hibernation by making this statement that there is no such thing as a quiet, continuous state, this is a fluctuating phenomenon around which we hang a term which is only descriptive and is not precise

Hock Yes One thing that comes from this idea is that, in the past, because of this concept it has been considered that every hibernator should equal every other hibernator, and every time one measurement is made, it is equivalent to another man s measure on another animal, even on another species, under other conditions One man can make his measurements at a high point in the cycle, in fact I can make my measurements at different times on these ground squirrels at different points in their cycle and the data are not entirely comparable

Behnke What happens with reference to body water and urine excretion, if these hibernating animals are deprived of water when they are awake? How long can they go without water and remain without food?

Hock During the wintertime?

Behnke No, during the summertime In other words, to what degree can they concentrate the urine?

Hock I have never studied the urine I have deprived them of water under experimental conditions up to 6 weeks, I have either deprived them of all food and water, or given them just dry food

Behnke Just all food and water? So that they were living off their own body fat and tissue? And they have gone how long?

Hock About 6 weeks

Kark Did they die then?

Hock They were starving for this period of time If they were given dry food only without water they lost weight at the same rate as they do when deprived of both food and water They apparently do not eat because of the lack of water I have not included these data in my discussion here, but I do have them

Behnke I think these data are extremely interesting

Hock I did this on three different occasions On the first occasion it was performed in the wintertime when I was trying to follow up an old idea of making animals hibernate by starving them I starved them and they lost up to 50 per cent of their body weight but did not hibernate I returned them to full rations after about 6 weeks and they gained this 50 per cent back, and more, in 2 weeks or so

Fremont Smith What was the ambient temperature during the starvation period?

Hock This was probably at about 3°C The other two occasions were during the summertime when I was trying to do something still different, and there was no temperature control at all The room was open to the outside air which in Anchorage would be from 10° to 20°C, perhaps even higher

Travell These were ground squirrels?

Hock Yes

Kark When taking dry food they died much more quickly

Hock I shouldn t say much more quickly It made no difference if they were getting no food or water or simply dry food, they lost weight at the same rate They apparently did not eat, having no water available

Burch What was the respiratory rate?

Hock I will come to that

Burch What do you think is the alveolar epithelial surface temperature? That would give some indication of the total cessation of water

Hock In my bibliography there is almost nothing about water balance or kidney Knowledge of the whole water phenomenon is completely lacking in hibernators There is a chance some work will be done now

ater

mal

studies by Schmidt Nielsen (24)?

Horvath I would like to try

Behnke These animals have a remarkable renal mechanism The density of the urine must be far beyond any limits we consider normal for human beings

Rodahl Isn t the same thing true for the male Pribilof seals, which apparently exist up to 2 months during the mating season without taking food, and apparently they do not drink either for extremely long periods?

Irving They take no food and probably no water

Rodahl Yes

Travell Dr Hock, why didn t the starved animals you described hibernate?

Horvath They probably did as soon as you gave them food

Fremont Smith You said you kept them at 3°C ambient temperature

Travell Was it to try to get them to hibernate that you deprived them of food?

Hock In this particular case, I think that they were not physically set up to hibernate at the proper time of the year For one thing there

were too many in a cage They rarely hibernate when there is more than one in a cage In fact, if they do, the others eat the one that is hibernating

Montgomery You can induce hibernation in a ground squirrel?

Hock Hibernation can be induced in hamsters, but I have never been able to induce it in a ground squirrel Some have, however

Travell Wasn t it the season in which they hibernate?

Hock Yes It was late in the year, in fact about February They were in quite good condition, and I do not know why they had not hibernated In February I started the starvation experiment, but none of them hibernated

Fremont Smith You did keep them in large groups?

Hock Not after I started the starvation Then they were in individual cages

Fremont Smith Even so, they didn t hibernate?

Hock None of them

Irving Dr Hock s figure illustrating the natural sequence of events of the ground squirrels—and perhaps I am anticipating what you are going to say—shows that the preparation for hibernation is a prolonged affair involving, for one visible sign, something like a month or so of intensive fattening These animals, of course, are not able suddenly to decide that they are going to hibernate They have to make up their minds 2 or 3 months in advance and go through a fairly prolonged set of cyclic, metabolic, behavioral, and other changes That can become very interesting

Erikson (25) illustrated one metabolic peculiarity in the preparatory period just before hibernation He showed that during that time, when the animals are fattening at an intensive rate, the respiratory quotients are commonly high, indicative of synthesis of fat from carbohydrate He also showed that during the wintertime, animals which were aroused from hibernation and were relatively lean, when offered plenty of food still would not overeat nor did the respiratory quotients at any time rise to levels indicating their ability to synthesize and store an appreciable amount of fat

Hock This indicates, I think the point that hibernation is a seasonal phenomenon which the animal must perform in a certain manner Dr Mayer, who is a contractor of this Laboratory, has taken ground squirrels to Los Angeles He keeps them in a cold room for their whole life and he also keeps the lights on for 24 hours a day These animals have no cycle He has destroyed their cycle They do not know what day it is, or what month it is or anything else

On the other hand, I try to study hibernation as a natural phenome

non I move my animals outside about the time of emergence, in

in a situation that corresponded to that of the wild animals, they were not just in a cage in a cold room, or in an enclosure of some kind and kept there so they lost their cycle I was interested in the seasonal cycle

Fremont Smith It is very important to emphasize both of your points, and also that hibernation is not at least for these animals, an isolated phenomenon but rather a part of a cyclic process Therefore, it is a broader thing, it has a preparation, and it has an end

Burch Would you say preparation for hibernation is very much like the preparation in a bird for migration?

Hock That was my introduction My concept is that hibernation is essentially the same as bird migration Only a few mammals hibernate, and these are the ones that cannot get their food As mammals are less mobile than birds, they hibernate instead of migrate The prepara tion is quite similar I shall discuss that in more detail later

Figure 28 depicts temperature variations during the entire period of activity in arctic ground squirrels I summed the points of the wild shot squirrels for 10 day periods *Unfortunately, I had to do that* The seasonal cycle is shown, with rectal temperature high at emer gence and dropping down at about the time the females come out Some of the low temperatures shown are those of females I have not divided them by sex The body temperature then rises to be tween 38 5° and 40°C for the rest of the active period There are small fluctuations which may not have much meaning Even in September a high temperature is still found, then temperature drops just before entrance into hibernation I must say that this is not very good statistically because there are different numbers represented at each point of the graph For example, on 20 June, there may be 40, and in September there may be 4 or 6 At the same time I shot these in the

same time I measured the temperature of long term captives, that is, squirrels that had been captive anywhere from 1 month to 4 years Their temperatures showed *no indication of cycle, and no correspondence in* any way with the wild condition This illustrates my point that it is necessary to know the conditions under which the measurements that you are comparing with your own have been made For example, Dr

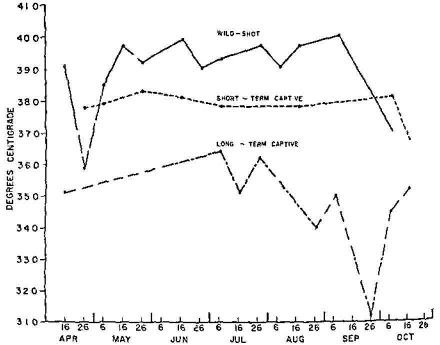

FIGURE 28 Comparison of 10 day averages of mean rectal temperature of wild shot, short term captive, and long term captive Arctic ground squirrels during the active season

Irving s (15) discussion of the Point Barrow squirrels may have represented short term captives He compared his data with Gelineo's (26) results on the European ground squirrels which may have been long term captives Therefore, these data may not be comparable This is the fault with much of the literature on hibernation You do not know exactly the conditions under which the data that you are comparing with your own have been collected Therefore, they are not always comparable

The thermoregulatory ability of ground squirrels is another point I would like to discuss It has been stated, as I have said, that hibernators have a more labile temperature than other mammals This is perhaps true, but certainly not significantly true, except during these periods just before and just after hibernation

It has been stated that the essence of hibernation is a transposition from the homeothermic condition during the period of activity to the poikilothermic condition during the period of hibernation I have used the term heterothermism to describe this, and have stated in print

that this is the situation More recently Suomalainen (27) has said all hibernators are primitive, that they lack thermoregulation, and that this distinguishing transposition from homeothermism to poikilothermism is because of the primitive thermoregulation I do not believe this is the case I believe, rather, that this is a case somewhat similar to that in bats, with the distinction that the thermoregulatory ability of hibernators while it may be a little less exact than that of true homeotherms, has two distinct levels One of them is the high level of activity during the summertime and the second is a different thermoregulatory basis during hibernation It is not poikilothermism during hibernation, it is, rather, a different setting of the thermostat, so that the high level has been turned down, then thermoregulation goes on but is geared to a different basis It is geared, perhaps, again to ambient temperature as in the case of the bats, but it is certainly geared to a lower level But the hibernating animal, in deep hibernation is not poikilothermic He is a homeotherm, with a different level of regulation of his temperature

Fremont Smith This is an interesting distinction of terms If the animal was dropped to a new, lower level and remained at that level more or less, regardless of variations in the ambient temperature, it seems to me you would have your point, but if you say that his new level is related to ambient temperature, you are almost saying the same thing as poikilotherm

Hock He does not stay right with the ambient temperature

Fremont Smith This is the point Would an individual bat stay at a fairly constant temperature, more or less, regardless of variations in the ambient temperature?

Hock No, he will fluctuate with the ambient temperature, within limits He will fluctuate back and forth as the ambient goes up and down, but if the ambient drops low, he will not go with it

Fremont Smith Not that far?

Hock No

Blair I agree with Dr Hock that this is simply a resetting of the thermostat the hypothalamus, for the hibernating animal, and it is not true poikilothermism

Dr A D Keller (28), of the Army Medical Research Laboratory has destroyed hypothalamic temperature regulation in dogs and their body temperatures remain just above environmental temperature If you drop environmental temperature down to 30°C the dog s body temperature will be 35°C, if you drop it to 28°C, it will be 33°C, etc It is a case where the hypothalamus is nonfunctioning and one of true experimental poikilothermism On the other hand hibernators do not

do that because the hypothalamus is functioning, but at a different thermostatic level

Fremont Smith Nor do the hibernating animals maintain a steady state, regardless of external environment, the way humans do They lie somewhere in between the poikilo and the homeo reset, at a new level Isn t that correct?

Blair Yes

Hock This is the reason I have used the term heterotherm or two different thermostat settings Earlier in the discussion, Dr Irving used it to mean lability of temperature Morrison and Ryser (29) have used it to describe the lability of temperature in the deer mouse, meaning animals with fluctuating temperatures I would like to suggest that the term *heterotherm* be used to describe different animals having different levels of thermoregulatory setting and not mere lability of temperature According to the derivation of the word, however, it can be either one or the other

Fremont Smith If we specify each time how we are using it, we can use it both ways

Hock Heterotherm in my usage, means a different setting of the thermoregulatory basis and in Dr Irving s usage it means the lability of temperature

Fremont Smith Would you agree with my point that the mere statement of a different setting is not good enough for the description of hibernation? You have to say both that there is a different setting but that there is also within that setting a relationship to ambient temperature which you don t have at the original setting of 37° and 38°C

Hock That is true

Fremont Smith It would be important to make those two statements The single statement of heterothermia will not be sufficient for the hibernator If so, he would be maintaining this level regardless of the ambient

Hock With the exception that, if the ambient temperature goes too low, the hibernator will not go with it

Fremont Smith Yes, exactly There is a limit to which he will follow the ambient

Hock It is very close to zero

Burch Is it not a much more complex phenomenon? There must be cyclic endocrine changes

Hock I would like to discuss that later There is a natural sequence of ... ed on the migration

of

define it is not good enough to describe hibernation, as you have de scribed it It is necessary to add that there is this other factor, too

Burch I wonder whether some of the experiments of Dr Hock were comparable to the cooling that surgeons use in man That is not hibernation

Hock There is a great distinction between the two, which Dr Covino will discuss

Meehan In spinal man, we see some effort at temperature regula tion Theoretically, there is little control of the peripheral vasomotor system Is there any relation between this and the phenomenon of cool ing that you see in hibernation?

Hock In the animal in hibernation, there is probably little peripheral circulation

Burch It is almost zero, if not zero?

Hock Yes

Tremont Smith Fever is a good example of the thermostat being set at a new level This may vary considerably, as there are usually two processes interacting, but in the case of the person who is running a fever, his thermostat is set at a new high and somewhat fluctuating level, which is largely irrespective of ambient temperature This is not what the hibernating animal does He is set at a new low level but also moves with ambient temperature until he gets down to this mini mum level which you say is close to zero It is essential to bring in fever as an example of close to pure setting of the thermostat at a high level

Carlson Isn t the distinction the level of setting of the animal s thermal regulation? If the animal s thermostat was set at 2°C and he warmed to 8°C, he would pant to prevent heating The resetting of the thermostat prevents freezing, *i e*, brings about thermoregulation below 2°C

Burton I don t think we have allowed Dr Hock to reach the essential point of difference between a poikilotherm such as a frog and [illegible]

there still is a reflex, and he wakes up, he cannot be frozen

Horvath It is possible to reduce the temperature of a dog to 24°C and maintain him at that temperature in an environment of, roughly say, 22°C He will stay there a long time Suddenly spontaneously, he will start rewarming Is he a hibernator?

Hock No

Blair If the dog is a laboratory produced poikilotherm by means

of a hypothalamic lesion, he will remain hypothermic when ambient temperature is lowered

Horvath That is not a normal animal

Blair It is not a normal animal unless the temperature is raised or something is done to alter the situation

Horvath He will do that, he will spontaneously start rewarming

Hock He will not spontaneously rewarm at much below 24°C

Horvath That, I think, is unknown at the moment I certainly think, if you keep his temperature at 24°C for periods of 3 or 4 days, every once in a while, some of these animals will start spontaneous rewarming after you have had them, say, more than a day There isn t a thing that can be done about it

Fremont Smith Perhaps this process has a relationship to the rewarming process in hibernation, but to ask, is he hibernating or not, is wrong, because there are no criteria available that sharply define this whole cyclic process which is included in hibernation

Blair Dr Burton has stated it It is simply that the hibernator has a protective mechanism available and it can work at the critical moment, whereas the poikilotherm has no protective mechanism available when it needs it

Fremont Smith Does it have a protective mechanism in this case?

Cotino This is an artificial situation

Burton I suppose that when what Dr Horvath describes happens it can be explained as a fluctuation in metabolic rate with a relative instability of the heat balance, but, definitely, if a dog is taken down to, say, 18°C, he has no protective mechanism that will come reflexly into play and prevent a lower drop

Blair I agree with Dr Burton If that occurs, you have blocked his protective mechanism from coming into play In our experience, if you drug an animal before putting him under a stress you may block his protective mechanisms against that stress

Horvath Now you are saying protective mechanism What mechanism are we blocking?

Behnke Would skin temperatures be of any help? As I understand it, in the hibernating animal, the skin temperatures are higher than the ambient air temperature Have you measured them?

Hock No, I have not

Montgomery Dr Burton s definition of a hibernator as opposed to a nonhibernator is very good, because it not only distinguishes between hibernator and poikilotherm but it distinguishes between hibernator and man or even the bear

Hock Let us say that during the process of arousal, the animal is

in an ambient temperature of 2°C and his skin is very close to 2°C, but his internal temperature, i e, the heart, liver, colon, and so forth, may be close to 4°C As he awakens from this low temperature, the blood is shunted anteriorly to the brain and to the interior region of the major organs It is preferential interior anterior circulation Dr Lyman (19), who has done this work, says that he has no evidence that there is a reduction in the posterior and the peripheral circulation during deep hibernation

In 1811 Saissy (30) said that when torpor is complete, the blood vessels on the periphery of the body are almost empty, the larger vessels are only half full, and the blood appears to be in a state of stagnation Thus it appears that there is very little posterior or peripheral circulation during deep hibernation At any rate during arousal the circulation is preferential in nature As a result, the cheek pouch temperature as determined by Lyman may have been 20°C when it was only 12°C in the rectum The animal arouses by warming the brain and the anterior portion first and the posterior portion last In fact, I have aroused animals until they had a rectal temperature of 37°C and then have put a needle thermocouple into the hindfoot and found the temperature there to be about 2 5°C which indicates that this is the last part that warms up

Fremont Smith What about the front feet?

Hock They warm earlier than this There is a very distinct difference between this process and the process that is shown in a dog rewarming from hypothermia or the process shown in the frog rewarming in direct relation to ambient temperature increase

Burch Lyman's (19)* experiments on the use of contrast medium injected into the circulation revealed that nicely He injected, at various stages of awakening, a contrast medium that showed that as awakening progressed the circulation gradually became re established more and more to the periphery, the last systems to be fully established were in the extremities and the tail

Blair What is the shivering pattern on reawakening?

Hock The shivering process starts very quickly, at least in the ground squirrels that I know most about In fact if a rectal thermo couple is inserted when the animal s temperature is 2°C, he starts to shiver rather quickly after this However what really happens is that the heart rate goes up first Lyman has shown this very well I once observed that the heart rate went from 4 to 68 beats per minute when

*Lyman C P and Chatfield P O Physiology of hibernation of mammals *Conference on Hypothermia of the National Research Council Subcommittee on Cardiovascular System* Washington D C Oct 28 29 1955 (Not published)

the animal s temperature had only increased perhaps 1/10 of a degree The animal is usually curled up and first uncurls and makes gross body movements During this time, the body *temperature is increasing very slightly* and then it starts increasing more rapidly Heart rate of course increases rapidly during this time and metabolism is also increasing

Fremont Smith The heart rate change is extraordinary It seems to me it suggests, really, very important and exciting experiments on enzymes, because this is contrary to the chemical law of temperature isn t it?

Hock Such experiments are the key to understanding hibernation

Travell Do they start to shiver first with their forelimbs?

Blair Yes, was it reflex shivering?

Hock Yes

Blair If it is reflex shivering it would be in direct relationship to the limb *activity*

Horvath The animals that I was mentioning do recover their body temperature They become perfectly normal In fact, one animal has been used on five different occasions and with one, the longest time that he was maintained at 24°C was 72 hours

Fremont Smith To be explicit, the ambient temperature constant was what?

Horvath It was 23°C

Fremont Smith The animal s temperature is about 24°C He then will start rewarming spontaneously

Horvath That spontaneous should be in quotes

Fremont Smith He will start rewarming and warm himself up to normal in spite of the ambient temperature

Horvath Yes even though we tried to drop the ambient to help the animal returned to a stable level When he gets to about 30°C he starts shivering

Fremont Smith It seems to me that you cannot dismiss altogether the fact that this is protective mechanism

Burton Dr Horvath used curare to get them down to these tempera tures If we say the curare was just wearing off, what is his answer to that?

Fremont Smith I would say it is a recovering process

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so markedly retarded this is rather an unusual situation

Blair Are we dealing with a physiologic or a pharmacologic mecha nism?

Horvath I don't know whether this is a physiologic protective mechanism or a pharmacologic wearing off

Fremont Smith Or both

Horvath Here is a preparation which remained relatively close to ambient, and spontaneously started up This goes back to my own feeling about hibernation, as Dr Hock brought out so nicely, namely, hibernation is not a static but a fluctuating state Sometimes, in spite of all we do, the animal will spontaneously get away from us This is the same sort of thing that happens in this type of preparation

Fremont Smith Maybe the very fact that he escaped from the effect of the drug is an indication of protective mechanism now being released

Horvath No

Fremont Smith This was 3 or 4 days later?

Horvath Yes

Carlson For 3 or 4 days they had essentially no temperature regulation The curare must wear off before 3 or 4 days

Horvath Their rectal temperature is 24°C Measurements of skin temperature, rectal temperature, muscle temperature, and right heart temperature all remain plus or minus one or two tenths of a degree of each other This animal is persisting at this very constant level

Carlson This is an important point We teach our students that temperature regulation is impaired below 33°C Dr Horvath's experiments suggest that after 3 or 4 days regulation occurs

Fremont Smith In a dog

Horvath Yes

Burton It could be pharmacologic because it is true, that when a

process When it is triggered, everything that happens helps it to wear off more quickly

Horvath You find urine in the bladder Very occasionally one of these animals voids spontaneously

Behnke When do you release these dogs from artificial respiration?

Horvath I never have them on artificial respiration The breathing rate is in the neighborhood of 1 or 2 every minute Minute volume is 50 or 100 ml

Behnke Curarized?

Cotino There was a recent article (31) on this Dogs were completely curarized and they were able to rewarm

Horvath The liver is involved in this

Blair Rats whether curarized or not, can be brought down to 10°C body temperature and will spontaneously rewarm at room temperature

Fremont Smith At room temperature?

Blair When put back at room temperature, they will rewarm from 10°C body temperature

Fremont Smith These dogs were rewarming from 23°C and the temperature maintained at 23°C Dr Burton says it could be pharmacologic, and I agree it could be

Hock It is evident from the study on temperature that I have just described for the ground squirrels, and from several other lines of evidence, that it is not correct to describe hibernating forms as merely hibernating or active Nearly the entire year is spent in preparing for hibernation, recovering from it, or in hibernation From the evidence of the body temperatures alone it appears that there are not two annual periods in so far as the temperature of hibernators is concerned but that four exist These are the low temperature of hibernation continuing in the ground squirrels from early October until late April, a short period of variable temperature from emergence until about mid June, then a period of relatively high and constant temperature from mid June to about mid September, and finally a period of lowering temperature in late September and early October preceding hibernation This is an illustration of the fact that in hibernation as in many other phenomena studies made in the laboratory should be correlated with

and to the

related

eaning

to the animal by making correlations of this type This has not been attempted many times in the past and I feel that it is one of the best ways we can understand the phenomena of animal physiology

In the past, for example, it has always been stated that hibernators are active at one time of the year and hibernate at another time, and comparisons have been made on this basis Such comparisons may be invalid I think I have shown that during the active period, such a simple thing as the body temperature changes It is almost certainly true that during periods of hibernation which we have heretofore thought was a steady state, there are cyclic phenomena which go on throughout hibernation And in fact, early hibernation and late hibernation are different phenomena There is an abundance of evidence of this in the literature

Next, I should like to turn to a brief discussion of metabolism Figure 29 is a graph of the metabolism of the little brown bat, *Myotis lucifugus*, from 2°C at the minimum metabolism, to the metabolism at the temperature of flight, which is 41 5°C It continues to 44°C where death ensued very quickly (6) The metabolism was minimal at 2°C and on one occasion, the temperature dropped accidentally to 0 5°C and the metabolism increased to a higher level This is a reflection of the fact that the animal has what may be called the alarm reaction' to prevent its temperature from getting to 0° or lower The animal s metabolism increases as the temperature falls to near 0° and his tem perature may go up too, but he will not normally allow the body tem perature to go below 0°

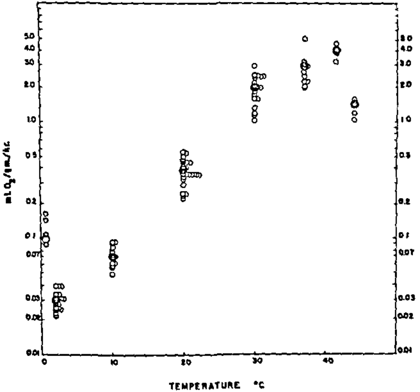

FIGURE 29 Metabolic rate of the little brown bat (*Myotis lucifugus*) in relation to ambient temperature The large circles are the mean values at each temper ature Reprinted by permission from Hock R J The metabolic rates and body temperatures of bats *Biol Bull* 101, 289 (1951)

Montgomery Is he more active?

Hock Apparently there is no change I have tried to do some experiments on ground squirrels to determine what happens but it is very difficult work There are three things that can happen The first is that as the ambient temperature falls to 0°, the animal s temperature will also fall to 0°, but if the animal decreases his temperature and allows it to stay there very long, he will die The second response is that the animal may start to awaken because of the stimulus of lowered temperature The third response is that the animal may increase metabolism and thus maintain temperature at about the same level as it was before Any one of these three things can and does happen

Figure 30 shows the body temperature and the metabolism of bats graphed together This indicates that the metabolism of bats, unlike that of other mammals or other hibernators, is geared to body temperature and not to ambient temperature It happens that body temperature is, of course, geared to ambient temperature, but one can study the metabolism of bats at any body temperature One cannot, however, study the metabolism of ground squirrels at body temperature of 15°C because it is a very transitory thing, for the squirrel is either warming or cooling when the temperature is at this point It thus appears that in other hibernators, except for bats, there is one level of metabolism during hibernation and another during activity, with a transitory phase in between which occurs when they are going into or coming out of hibernation In the case of the bats there is a distinct level of metabolism at any level of temperature within the normal range

Carlson There is a significant change in temperature

Hock Figure 31 shows the metabolism of ground squirrels These data are taken from Dr Erikson s (25) Point Barrow studies I have simply put in this figure his means and his extremes of the active, quiet and resting range Dr Erikson said there is essentially no change in metabolism from 10° to 50°C If the active points were left off, this would be true Sullivan and Mullen (32) have studied the same animal at Point Barrow and said that there was no change in metabolism from 25° to 5°C in active ground squirrels At temperatures below 5°C, the metabolism suddenly rises No studies have yet been made on the hibernating metabolism of the Arctic ground squirrel, but abundant studies have been made on ground squirrels of other species

In the bats the ratio between the highest level of metabolism at 41 5°C and the lowest level at 2°C, was 140 to 1, that is, the metabolism during deep hibernation at 2°C was 1/140th of that found when the body temperature was 41 5°C but the bat was not flying In other

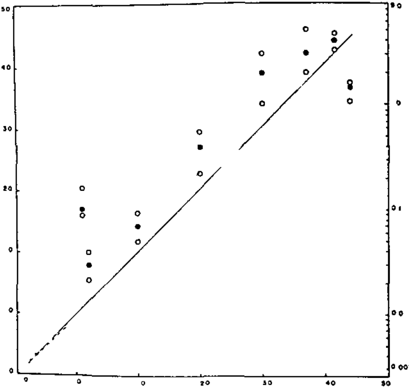

FIGURE 30 Metabol c rate and body temperature of bats in relat on to ambient temperature The dashed l nes enclose the body temperatures plotted in Figure 22 The dots are the mean values from Figure 29 and the circles represent the extremes

hibernators this figure varies from 1/50th to 1/100th of the normal active metabolism

This apparently is the real basis of hibernation for it seems that the animal benefits from hibernation because he can either store food in his burrow or on his body in the form of fat and then he can for a period of 4 to 8 months use this food at a tremendously reduced level of metabolism and thus pass the time of food scarcity safely

I had hoped to do some work on the metabolism of bears during the denning period this past winter but the weather was too mild and the bears did not stay in their dens for any lengthy period of time However

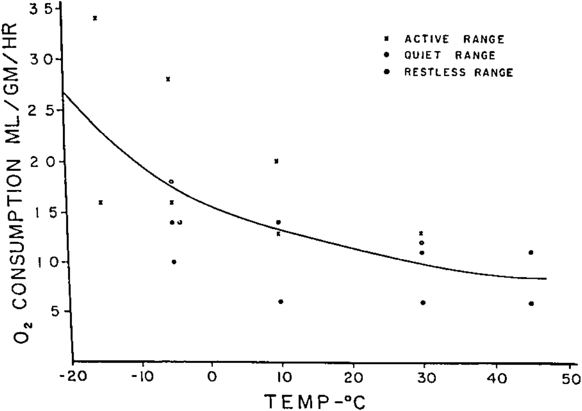

FIGURE 31 Metabolism of active Arctic ground squirrels The line represents the best approximation to mean value Re drawn, by permission, from Erikson, H Observations on the metabolism of Arctic ground squirrels (*Citellus parryi*) at different environmental temperatures *Acta physiol scandinav* 36, 66 (1956)

I have done metabolism of active bears in the fall and in the spring, and found (Figure 32), as Dr Irving showed earlier, that in the wintertime there is a long thermoneutral zone in which metabolism essentially does not change This zone is from about −10°C to somewhere over 20°C

Burton Would you label the axes?

Hock Yes, one is ambient temperature in degrees and the other is metabolic rate as shown by oxygen consumption

In the fall, the thermoneutral zone is a little more precise than it is in the wintertime and the metabolism is a little bit higher This has also been shown to be true in Dr Irving's studies (33) on red foxes and other large Arctic animals There is no essential difference in the metabolic rate shown by active bears and that shown by red foxes and other Arctic species However, the picture as shown during the winter denning period might be quite different The bear, with his temperature of about 30°C during the wintertime, is very close to the body temperature produced by hypothermic anesthesia in man In fact, bears would make excellent subjects for students of hypothermia During this reduction of body temperature in man from 37° to 30°C there is a con

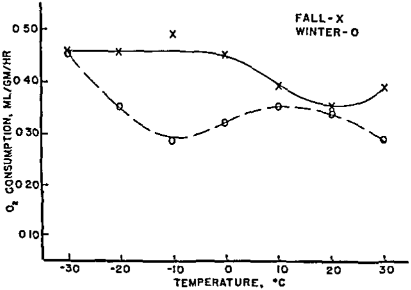

FIGURE 32 Metabolism of an active black bear in fall and late winter in relation to ambient temperature

comitant reduction in metabolism of about 25 per cent If the s holds in bears, the small reduction in body temperature will perl allow the bear a metabolic saving of at least 25 per cent This ap ently is the basis of the bear s ability to pass the winter successfı The phenomenon of hibernation in bears is, in some respects, n interesting than is the phenomenon of true hibernation as shown by ground squirrels The bear is an animal with a small reduction in b temperature, and we assume that he has a reduced metabolism al with it Yet for 6 months of the year in Alaska bears are in their d they do not eat or drink, and during this time the young are born the females must therefore nurse them It thus appears that there tremendous strain on the metabolic reserves of bears that is m greater than that imposed on the ground squirrels with their greatly duced *metabolic rate Thus, the phenomenon in bears is a much m* demanding situation than true hibernation

Montgomery When the whole story is known about a great m different mammals, won t there be a nest of curves, from man at the to the ground squirrel at the bottom, with the bear in the high midd Won t the phenomenon have to be called by some name other tl hibernation?

Hock There is abundant precedence in the literature for c ating a series of terms for slightly different degrees of the same p nomenon If we must name degrees of hibernation now, we will ha the true hibernators those rodents that have been mentioned, at t bottom Let us say that their temperature is reduced to 2°C The b also might be in this same classification, although I regard them *different* Up a *little higher* we have the bears with a much less pı found change In between the bears and the true hibernators we ha another group of rodents which have been very poorly studied Tl phenomenon has been called partial hibernation, but this term h two different meanings It has meant, in the first place, those anima that reduce their body temperature to a degree less than that of the tr hibernators

Montgomery It isn t too little It is a reduction to 25 per cent c metabolism

Hock We assume This term has also been used to denote anima like the eastern chipmunk that presumably hibernate for short perioc of time It develops that the prairie dog of the western plains does bot of these things (34) Its temperature has been recorded down to abou 14 5°C in an ambient temperature of 9°C These rodents therefore hav a reduction in temperature to somewhere between *14 5° and 22°C*

So, as you say, there is a spectrum, and I think this is a valuable poin

to make Unfortunately the word hibernation may still have to mean as many things as it did before, but I would like to see more restricted meanings placed on the terminology

Fremont Smith I should like to make a suggestion for analogy in terms of temperature control and respiratory control There was a time when it was thought that there was one respiratory center Now we recognize there are more than one, and that they control different aspects of respiration I suspect that there are more than one center in the hypothalamus you mention, Colonel Blair, and that they control and regulate temperature regulation, and I also suspect that one of them might deal

the other, f

of body te

different phenomena Perhaps three or four are involved And the reason that we get into this confusion is the fact that we don t have the same phenomenon but we have the same phenomena operating, and each operating at a different level of intensity

This would give, then, a series of regulating mechanisms thrown into operation at different levels in different animals and would I think,

causes involved in temperature regulation in animals exposed to cold

Hock We must keep in mind the fact that many animal phenomena have not become fully developed I have already said that hibernation

these rodents that exhibit what may be termed partial hibernation are in a process of attaining it and that they are halfway Still another phylogenetic group of mammals the carnivores are starting in this direction It is a tempting thought to postulate, but I am not sure that I would ever defend the point

Fremont Smith It fits with the whole organization of the central nervous system from the evolutionary point of view

Hock Unfortunately we do not have enough additional evidence on either of these two groups to know if in other phenomena than temperature and metabolism they are reaching toward the same sort of situation found in what we call true hibernation

The respiratory quotient in hibernators has been given many times as peculiarly low In fact values of 0 28 and 0 43 are not uncommon in the older literature Benedict and Lee (21) and more recently,

Dontcheff and Kayser (35) worked on this and found that these are artifacts, that the R Q (*respiratory* quotient) during hibernation is, indeed, 0 7, as it should be Dr Irving has mentioned Erikson s study (25) at Point Barrow in which he found that active hibernators, when actively depositing fat had an R Q *from* 1 0 *to* 1 4 *This is at* ambient temperature above 5°C If the ambient temperature fell below this, the R Q fell again to 0 7

Horvath Why do the animals have to live on fat? Why can t they convert to carbohydrate and therefore have a lower R Q ?

Carlson Aren t they the same?

Fremont Smith Would they get a lower R Q if they converted?

Hildes They would have to convert it first, and the net result would be the same

Burton If you caught them in the period when they were converting and not burning, you would have a low R Q

Kark What happens to the blood ketone levels when they produce fat? Do they have high ketone levels?

Hock I do not recall any values for these levels

Kark Have they been measured? This would imply a different sort of metabolism to those of us who starve and use up fat We build up ketone bodies

Hock There is a very good question as to whether the basis of nutrition during hibernation is direct usage of fat or of conversion of fat to glycogen This has not been studied in a direct fashion and we hope to make such a study here

Behnke Isn t it possible to introduce gaseous anesthetic into the den and anesthetize the bear, and then make some of these very important blood studies under condition of anesthesia? Have you considered the feasibility of this procedure?

Hock Yes, Dr Svihla (16) attempted this one time on the bear The bear was taken into a squeeze cage and given nembutal A reduction in temperature was found during the anesthesia This bear was outside in very cold weather and the rectal temperature fell to 22°C

Behnke With cyclopropane and other anesthetics there are many interesting things that could be done, particularly with small animals With intravenous fat emulsions, animals could be kept, perhaps, in a state of hibernation and fed slowly over a long period of time

Hock To me this seems to be a very difficult procedure I do not approve of anesthesia as a tool in studying hibernation Hibernators are remarkably finely balanced animals and almost anything that is done to them causes a cessation of hibernation

Behnke I don t mean nembutal

Hock Any kind of anesthesia

Behnke Gaseous anesthesia?

Rodahl Years ago an attempt was made to chloroform a bear here, and the bear died from causes unknown!

Hock Figure 33 shows the respiratory rate for bats at various temperatures As is evident, respiratory rate also varies in a direct fashion with body temperature until the body temperature gets rather high and then the respiratory rate rises more rapidly Respiratory rate during hibernation has been studied many times in several hibernators The respiratory level falls to 4 to 8 per minute, and there are long periods of apnea, Cheyne Stokes breathing and other respiratory phenomena Often there are several respirations in a minute and then a period of 3 or more minutes without any respiration at all followed by a burst of Cheyne Stokes breathing and so on

Figure 34 indicates heart rate during arousal from hibernation It

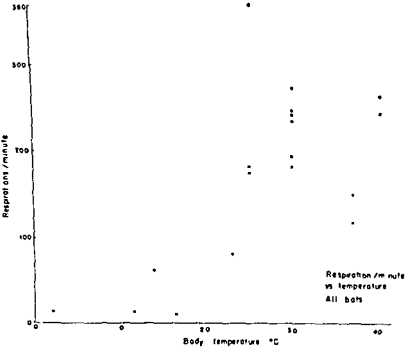

FIGURE 33 Respirations per minute of bats, in relation to body temperature Data from literature and personal study

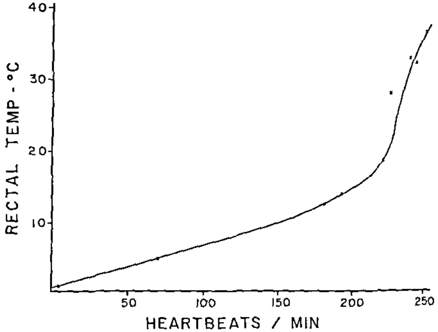

FIGURE 34 Heart rate of Arctic ground squirrel during arousal, in relation to rectal temperature

may be seen that the heart rate in deep hibernation is about 4 per minute These low levels have been abundantly proven by many other investigators, of whom Dawe and Morrison (23) have been the most recent Studies on various animals indicate that the heart rate during hibernation may be between 2 and 7 beats per minute

Crismon What animal is this?

Hock This is the ground squirrel, and it is during arousal, starting from a beat of 4 per minute and going up to 68 as the body temperature rose a fraction of a degree Finally, when the animal reaches its normal body temperature, it is about 250 or 270 beats per minute Dawe and Morrison (23) have given a figure of over 600 beats per minute in the hamster on arousal from hibernation

Talbott Is that a regular rate?

Hock Quite regular

Montgomery What is the hamster's normal rate? Below 600, isn t it?

Hock Yes it is The high rate is the same sort of phenomenon as the overshoot in metabolic level During the early stages of arousal, the beat is not regular, but, rather, it may come in bursts Also, there

are periods when there may be no beat at all, or there may be just the loss of a beat or two

Burch Was it a normal sinus rhythm?

Horvath Yes

Burch Even though they come in bursts, were they of sino auricular nodal origin?

Horvath Yes

Hock Lyman* has also studied the difference between hibernators and nonhibernators relative to the influence of temperature on the persistence of the heartbeat in the isolated heart He finds that hibernators in general differ from all nonhibernators in the heartbeat response to environmental temperature The woodchuck heart still shows a beat at temperatures of +1° to 2°C The ground squirrel heart is still beating at −1°C, at which time his apparatus ceases to function The chipmunk and the hamster show heartbeat at 3°C It thus appears that in all species of hibernators the heart is beating at temperatures of 3°C or less In contrast, nonhibernating rodents have cessation of heartbeat at temperatures of 12°C The only exception to this is the cotton rat which has shown persistence of the heartbeat at 7°C It has been maintained in the past, as I have already said, that hibernation is a primitive condition Lyman wished to check this He was able to secure some mountain beavers, *Aplodontia rufa*, which are considered to be the most primitive rodent He found that they acted exactly as did the other nonhibernators, that is, the isolated heart stopped beating at 12°C This cessation of beat was not related to the size of the animal or to the size of the heart He feels from this evidence that all nonhibernators are distinct from all hibernators in this one phenomenon It appears, therefore, that hibernation is not a primitive condition, that it is, perhaps, an advanced condition It is quite distinct from a primitive state

I should now like to discuss the natural history of the ground squirrel as it relates to its hibernation and will start out with the squirrel in hibernation at the beginning of the calendar year In the spring, on 21 April, in my study area near Anchorage, and at nearly the same date everywhere in Alaska, the squirrels begin to emerge By accident, my first year of

I was not re

1952 the sc

April I could find no open burrows, but on 21 April some squirrels emerged This precise date apparently holds for 4 years of record I am discussing only males, as they come out first In 1955, there

*Lyman, C P Unpublished This work was done under contract with the Arctic Aeromedical Laboratory at the Ladd Air Force Base Alaska

TABLE IV

Dates of Emergence From and Entrance Into Hibernation of the Arctic Ground Squirrel Over a 5 Year Period (Remarks on Snow and Normality of Season Are Included)

Spring		Fall
	1950	
No observations		Last date appr 2 Oct Cold light snow 1 Oct Normal season
	1951	
First date appr 22 April 3 snow bare spots Normal season		Last date 5 Oct Cold heavy snow 1 & 5 Oct Early season
	1952	
First date 21 April 4½ 6 snow no bare ground 3 weeks late season		Last date 7 Oct Warm (+10°C) rainy Late season
	1953	
First date 21 April 2 4 snow ½ bare ground 2 weeks early season		Last date 9 Oct Warm clear 1st snow 18 Oct Late season
	1954	
First date 21 April 2½ 4 snow part bare 3 4 weeks early season		Last date 12 Oct Cool light snow Normal season
	1955	
None seen until 27 April Heavy blizzard on 16 April 5½ 8 snow late season		No observations

was a very heavy blizzard on 16 April so that I was unable to get up to the mountains to look into the situation By the time I did get there, it appeared that the squirrels had not emerged until 27 April I am not positive about this date because finding emerged squirrels in the springtime is very difficult under any conditions The squirrel comes up through the snow which may be 4 to 8 feet deep and he may walk on the snow surface for a few feet, return to the burrow, and perhaps not appear until the next day, when he emerges for another few minutes

Table IV shows that regardless of the amount of snow, the amount of bare ground, whether the season is normal, or late, or early, or other

were seen are progressively later, but this is because I was there each year a little later than the previous year There were very few squirrels active after about 1 to 5 October, and these all appeared to be young ones which apparently had not yet attained sufficient fat to hibernate

The female squirrels appear to go into hibernation in September beginning about the 10th The adult males are all in hibernation about 1 to 5 October, at which time they have attained the weight of about 700 to 750 grams Again, despite the fact that the seasons were entirely different, either early or late, raining or dry, with snow or without snow, *the squirrels apparently disappeared into hibernation at about the same time*

There is no meteorologic phenomenon that is this precise except for the length of the day This is known to be the reason that birds migrate southward Because the day length decreases in the fall, there is less incident light acting on the pituitary and the bird migrates southward This appears to be acting in the case of the ground squirrels

In other species of hibernators, such as the woodchuck of the east, the animal goes into hibernation at the time of maximum food abun dance It is not at all cold The first postulated cause of hibernation was cold, the second was lack of food Most hibernators go into hibernation when there is yet abundant food It has been suggested that the stimulus is dryness, however, this cannot hold for the Arctic ground

the controlling date of emergence

Hock This must be true The squirrels are at least 8 feet under the snow and ground in the spring I tried to duplicate these conditions experimentally and I took squirrels that had been outside in large cages

and moved them inside to small cages in my hibernating room on 21 June There was no temperature control, and ambient temperature in Anchorage might vary between 15° to 30°C during this time I reduced the day length so that on 1 August, the period of light was equivalent to that on October 1 in the field I also tried several other leading theories culled from the hundred or more that have been advanced to see if these might modify my results It turned out that very few of the squirrels hibernated under any of the regimes, although they became excessively fat under the reduced light regime However, the Anchorage environment in which I was operating was not very good, as there was heavy traffic in the morning and afternoon near the area There was also an airplane take off strip directly over the animal house and this, of course, stopped functioning at dark I hope to duplicate this experiment here at the Ladd Air Force Base, where the local environment is quite good At any rate, it appears that the emergence from hibernation in the spring and the entrance into hibernation in the fall is very precise in nature in the Arctic ground squirrels

Horvath Do you have any speculations on this very peculiar pattern of events? The female goes in earlier than the male and comes out later yet she shows the greater amount of activity

Hock Figure 35 is a graph of the mean weights during the year from the date of emergence to the date of entrance into hibernation When the squirrels emerge from their burrows they are quite fat, the males weighing characteristically over 500 gm and the females somewhat less There is no food available at this time as the entire area may be covered with snow, however, there may be some bare ground with dried seeds and plant stems as the only food The whole population, therefore, loses weight Females emerge on about 1 May and breeding takes place almost at once The young are therefore born about the end of May and the females must begin to nurse and feed them Starting in mid summer, after the time of emergence of the young from the nest, the population rapidly increases in weight The young, of course, must gain sufficient fat to spend the winter in hibernation

Montgomery You say they have no food Doesn t it seem as though they have poor food but a considerable amount of it, or twigs, or some thing else, since they lost so little weight during the month after emergence?

Hock They have mostly empty stomachs at this time I had, at one time, thought that the basis for the rapid increase in weight beginning in mid summer was that the squirrels start eating seeds which are available about this time In fact, I thought that when the squirrels first emerged from hibernation they ate nothing until some time in late

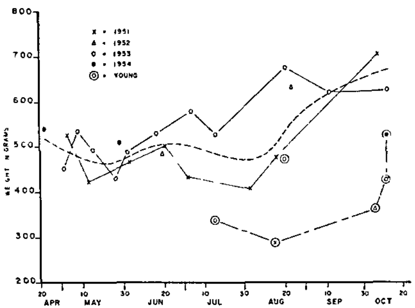

FIGURE 35 Average weights of Arctic ground squirrels in different years, plotted by date The dashed line represents an approximation to average

May when grass was available, and that grass simply held their weight at about a constant level, until the seeds were available and thus allowed the animals to fatten rapidly However, I analyzed about 100 stomachs taken over the entire year of activity and found that the animals ate grass during the whole summer If there is a difference in the rate of fat deposition, it is not because of the difference in food stuffs It may be a result of a different metabolic rate caused by decreas ing daylight Or it may be that some other factor is operating in this fashion I do not know The only physical finding I have is that the stomach is very enlarged in late summer When the squirrels first come out, the stomach is tiny and thick walled and just before entrance into hibernation it is very large The food throughout the entire active period is grass after it has become available

Fremont Smith If one looks at the islands of Langerhans, and if insulin plays a part, one might find hypertrophy during the period of fat deposition

Hock That is a good point, but I did not investigate it Figure 36 shows a squirrel within a day or two of the time he emerged, the squirrel weighed 550 gm at this time and still had much subcutaneous

and perirenal fat It had probably weighed about 750 gm just before it went into hibernation It had thus lost 200 gm of fat during the hibernating period This fat that is still present will be quickly lost during about one month in the vicissitudes of breeding, fighting, and running around without sufficient food intake

Burch Did the squirrels store a great deal of food?

Hock These squirrels store very little food I never looked for it, but food has been found stored in the Arctic ground squirrel by Mayer (37) near Point Barrow, and by Krog (38) near Kotzebue About a double handful would be the average

I should now like to make a few remarks on the breeding cycle because I think this answers, in part, Dr Horvath s question It behooves these animals to do everything as rapidly as possible during the short period they are active and one of the things they must do, to perpetuate the species, is to allow the young sufficient time to gain adequate fat to hibernate It seems as though there are several ways in which hibernators can shorten the breeding cycle in order to give their young additional time

The first is to make no adaptation whatever, which is apparently what the European hedgehog does In England (39) it appears that this animal only hibernates about 3 months of the year and has sufficient time on emergence from hibernation to rear two broods of young during the active season Spermatocytes and spermatogonia are present throughout the entire year

The second adaptation is that shown by bats (40) Spermatogenesis occurs in the fall and the bats breed at this time The sperm are stored in the vagina of the female for the period of hibernation When the females become active in the spring they ovulate within about 3 days and fertilization occurs at that time The bat has therefore not wasted the period of time necessary for spermatogenesis on becoming active in the spring because the sperm is stored within the female over the period of hibernation It also happens that the male bat may still breed in the spring of the year thus indicating that its sperm is still active

The third adaptation is present in bears, in which there is discontinuous development of the embryo Fertilization occurs at time of breeding in the latter half of June but the young are not born until about 15 January in the dens There is, therefore, a gestation period of about 7 months The bear is the smallest newborn placental mammal in relation to its mother s weight at the time of its birth There appears to be discontinuous development of the embryo during the period of gestation If there is any value to the bear from this development it appears to be that she does not have large offspring during the winter

FIGURE 36 An Arctic ground squirrel a few days after emergence from hibernation showing extensive fat deposits remaining

denning period when she must rely entirely on her own body resources for the creation of nourishment for the young The offspring weigh about ½ lb and there are usually two By the time they emerge from the den 6 to 8 weeks later the total weight of the two cubs is perhaps 15 or 20 pounds

The literature does not make any statement about this fact but it appears that the marmot at least in Alaska also shows discontinuous development I have a record of a marmot taken on 6 May in which the embryos were 2 5 cm long although I had previously thought that marmots did not even emerge until 10 May It appears also from further field work that they emerge about 1 May Obviously there has not been time for embryos to have grown to 2 5 cm in length even if fertilization had occurred on the day of emergence It therefore appears that marmots may also show this discontinuous development

Fremont Smith Do marmots store sperm too? That is the implication

Hock No I think fertilization had occurred development had begun and then stopped This is known to happen in other mammals

Ground squirrels appear to show a still different type of adaptation although cell growth is not supposed to occur during hibernation and apparently hematopoiesis does not occur It appears that male ground squirrels on emergence in the spring on 21 April have spermatids present Then by 1 May the date on which the females emerge there are motile spermatozoa The lumina of the epididymis are completely filled with them The testes in many cases are descended and scrotal The ground squirrels are therefore capable of breeding at the time the females emerge The females emerge with enlarged follicles and appear to be ready to ovulate at that time They breed within 1 to 5 days from the time of emergence This indicates that cell growth may be occurring during hibernation at least as far as the gonads are concerned

The question has been brought up as to whether this cell growth occurs during the periods of reduced temperature of deep hibernation or during the periods of periodic awakening I cannot answer this of course At any rate the squirrel naturally emerges ready to breed This appears to be the reason why the male squirrels emerge before the females so as to enable the spermatids to complete transformation to spermatozoa

The entire life cycle of the ground squirrel in Alaska and apparently the entire life cycle of hibernators in any area is geared to the fact that they must hibernate Therefore as Dr Irving has pointed out it is a seasonal change with phenomena occurring in a proper sequence Attainment of sufficient fat is gained in response to the change in

length of day There must be many other occurrences in the animal preparing for hibernation It appears that all facets of his life history and perhaps of his physiology are geared to the fact that hibernation is going to occur

Burton How many hibernations does an individual go through before he dies?

Hock One for each year of his life, in normal circumstances This would be perhaps 5 to 10 in the ground squirrel as this appears to be his potential longevity

Figure 37 shows the normal situation during arousal from hibernation in which the ambient is right around 0° Arousal occurred in *one of these animals in 5 hours, however 2½ to 3½ hours are more* normal The only stimulus given to the animal was the insertion of the rectal thermocouple A rapid rise of about 20°C is indicated on one squirrel in about that many minutes This is unusual Normally the rewarming is much slower

It does not appear that ground squirrels really do hibernate in active permafrost layers On the Arctic coast of Alaska where the ground thaws annually to a depth of 1 to 4 feet and freezes in the wintertime, ground squirrels are not found in the active area They are found in

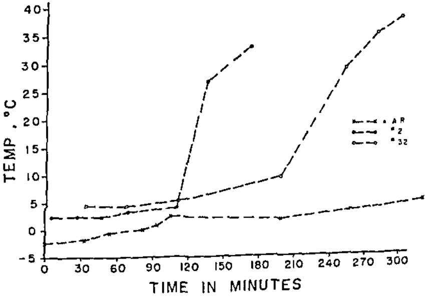

FIGURE 37 Rectal temperature of the Arctic ground squirrel during arousal from hibernation when exposed to normal ambient temperature

the sand dunes or river banks above the level of the surrounding active permafrost area This ground, of course, freezes also, but it is not real permafrost A small sand dune may have a large number of burrows with none in the low ground nearby However, I still wished to see what would happen when the squirrels were subjected to very low temperatures Figure 38 indicates an extreme exposure to temperature where hibernating squirrels had a rectal thermocouple inserted and were suddenly put outside in air temperature of −10° to −15°C

Figure 38 shows the reaction This is a profound exposure to something far below 0° All squirrels showed a drop in rectal temperature on first exposure One of these animals shown here at first dropped his temperature, and then suddenly awakened Another had a rectal temperature below 0° and still recovered from the exposure One squirrel was completely frozen peripherally with no resultant damage although the feet did slough off He lived for 2½ years after this incident

The third possible reaction is that the squirrel may maintain roughly the same temperature, and the marmot shown in Figure 38 did just that This may be because he was a larger animal and therefore cooled less

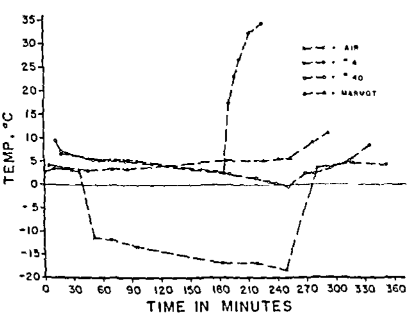

FIGURE 38 Rectal temperature of Arctic ground squirrels and a hoary marmot during arousal from hibernation, when exposed to severe cold stress

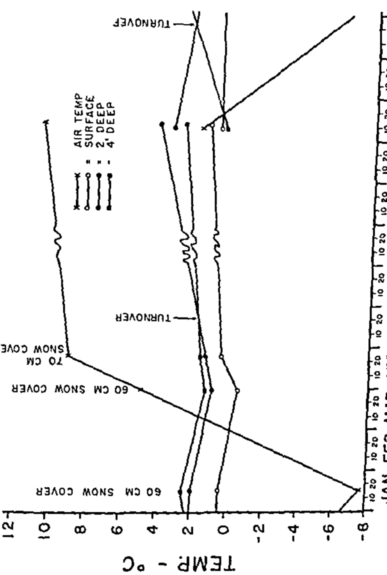

FIGURE 39 Ground temperatures at various dates in study area in Little Susitna Valley, Talkeetna Mountains, Alaska

rapidly His temperature remained steady for about 6 hours and then started rising very slowly

Kark If you hadn t pulled the animal out when he was down below 0°, would he have died?

Hock There is another one that went down below 0° on this same occasion and stayed at that level for 4 hours He did die

Kark Without waking up?

Hock Yes He was not dead when I took him out but he never re covered Whether some animals are slightly less resistant because of lower nutritive reserves or not I don t know However this is a very *severe exposure and it would not normally happen that an animal hiber* nating in a burrow would be subjected to a temperature of −20°C

It is perhaps more common that the squirrels waken in response to such exposure but it is possible for them to drop their body temperature to a point slightly below 0° briefly This was an exposure of several hours

Figure 39 shows ground temperatures taken at an installation in my study area near Anchorage and there is little resemblance to the Arctic Coast permafrost zones as there is no permafrost in these areas On 9 October I began this study and a few days later there was a very heavy snowfall The temperature at the depth of 4 feet the zone where the squirrels are in burrows never gets below zero during the entire year Unfortunately I did not make a reading during the summertime and thus I have shown a break in the line Actually the summertime ground temperatures may have been higher than shown here Ambient temper ature above ground is shown and also the amount of snow cover which is on the averge of 60 to 70 centimeters

Hildes What is the turnover?

Hock The turnover is when the deeper ground temperature and the relatively shallow ground temperature meet and change The tempera ture at 4 feet depth is cooler during the summer and warmer during the winter than that at the 2 foot depth

To summarize my remarks hibernation is not a steady state but the animal whether he is hibernating or active is undergoing a continual process of change Therefore care must be exercised when comparing data from one hibernator with data from another hibernator or even from the same species at different times It is important to point out that hibernating animals during their active season are not comparable to each other at different times because of the possibility that different times in the cycle are being measured We cannot thus say This is the active season figure and this is the hibernating season figure and

TABLE V

Annual Energy Budget for a Nonflying Little Brown Bat (*Myotis lucifugus*)

Date	Decimal Fraction of Year	Time Active (per cent)	Fraction of Year Active	Time Asleep (per cent)	Fraction of Year Asleep	Body Temperature (°C)	Metabolic Rate (cal/gm/hr)	No of Hours	Total Calories for 6 gm Bat
1 November to 1 May	0 500	2	0 010			37	13 770	88	7 26
				98	0 490	5	0 240	4292	6 36
1 May to 1 June	0 083	20	0 017			37	13 770	126	10 38
				80	0 066	8	0 288	604	10 44
1 June to 1 September	0 250	25	0 062			37	13 770	540	44 52
				75	0 188	20	1 89	1620	18 36
1 September to 1 October	0 083	20	0 017			37	13 770	126	20 38
				80	0 066	16	1 728	604	6 30
1 October to 1 November	0 083	10	0 008			37	13 770	73	6 00
				90	0 075	7	0 270	657	10 62
									130 62
Estimate for a year at rest with a body temperature of 37°C.									726 00

therefore these are the differences There is a constant change in many respects

There must be some attempt made to correlate physiologic findings and laboratory studies with field observations, in order to make the results more meaningful from the point of view of understanding the animal, the cycle which it may be undergoing and the point in the cycle at which it may be at the time the measurements are made

Physiologists and laboratory scientists are interested in phenomena and often lose sight of the fact that these phenomena are being conducted in an animal s body On the other hand the field scientist is so engrossed in the study of animals as animals that he is not interested in the more fundamental levels of their functioning, which are of major interest to us

From Figures 29 and 30, I have calculated the total resting energy metabolism of the bat for one year (Table V) I have assumed that the bat hibernates for 6 months, that every time he comes to rest his body temperature falls and he has a lower level of metabolic expenditure, and that this varies with different seasons of the year

Burch Were those kilocalories?

Hock Yes, it is 130 kilocalories This is not including energy expenditure in flight, but it is the metabolism of a resting bat at all temperatures to which he would be exposed for a year

Burch What would be the total number of calories in the whole animal s body?

Hock This is about a 5 gm bat

Burch His body turnover of energy would be many times that represented by 5 gm of animal tissue wouldn t it?

Hock Yes Rubner (41) and others have stated there is a rough correlation between body size and longevity I am not going into this debatable point

I have calculated from Pearson s (42) figures that a 3 6-gm shrew used 2,628 kilocalories in a year There is no such thing as a resting shrew, of course Hamilton (43) states that the life span of a shrew is 16 months Therefore, the total energy expenditure during the life time of the shrew is about 3,500 kilocalories At that time the maximum age of a bat of this species was 14 years * and I calculated a life expenditure of about 1,820 calories I thought that the difference between these two figures was a result of inherent errors in the assumption plus the fact that the energy of metabolism during flight was not taken into consideration One of these same bats, then 14 has recently been found still alive at the age of 20 years His total resting energy con

*Griffin D R Unpublished

sumption is now 2,600 calories on the basis of my assumptions If we add to this the energy of flight, which is undoubtedly quite high, we may come out with the two figures being actually quite close to each other I am not trying to support Rubner s hypothesis, but I simply say that it appears that the phenomenon of hibernation may act to increase the life of the animal because of the consequent con servation of energy In other words, as the bat is not using much energy for half the year, he may live twice as long I must interject another caution to myself at this place and say that I have tried to extend this assumption to the ground squirrels I have considered that the ground squirrel should live from 8 to 10 years, and yet I have been unable to keep one captive for longer than about 4½ years The most promising candidate, unfortunately, hibernated early one year and was eaten up by his cagemates So, I really don't have conclusive evidence

Burton I also wondered whether, in the ground squirrel, the same condition exists as Bigelow* of the University of Toronto finds in the ground hog of Ontario He says the farmers never find dead ground hogs except in the burrows The animals hibernate, several in one burrow, and he thinks that the life of these hibernating animals is terminated by their going into hibernation and never waking up Is this true?

Hock It is very likely the case I have not mentioned this but there is what the older workers called morbid hibernation, by which they meant that the animal was in such bad condition that he could not maintain his high temperature Such animals went into a state of hibernation, even perhaps in the summertime I have had this happen twice and both cases appeared to me to be caused by sunstroke The animals did reduce their temperatures to quite a low level, but died I have recently had six squirrels become torpid while captive in the field from causes not attributable to sunstroke Since this was the period of the year (June) when there is minimum weight and poorest condition in the squirrels, I feel that this is nearer to the older worker s morbid hibernation None of the six animals recovered

Talbott Within how short a time?

Hock About 12 to 24 hours, but there was reduction in temperature right down to ambient temperature

Talbott They could be in the dying state, then, when they went in, if they died within a period of 12 hours, possibly?

Hock Apparently so It also sometimes occurs that if the bear is

*Bigelow W G Personal communication

not sufficiently fat enough in the fall he will not go into the den, but will stay active Eskimos in the Brooks Range (44) tell about the ice-encrusted grizzly bears that were active in the wintertime Eskimos were very afraid of these in the days when they took bears by means of spears because they couldn't hunt them very well

If a wild bear is not fat, it will not go into the den in the wintertime In contrast, a ground squirrel that is not sufficiently fat in the fall will hibernate, but will not be able to pass the winter successfully I have had this happen in the cages Usually such animals are young and very small and they do not yet have sufficient fat to last the winter

Figure 40 illustrates one difference between hibernation and hypothermia These two states have been thoroughly confused, perhaps because the French unfortunately used the term artificial hibernation to describe hypothermia One difference is shown here this is the heart rate of a ground squirrel going into hibernation It falls from an initial point of 250 beats per minute down to 4 beats per minute, and a rectal temperature close to 0°

In contrast, the dog, which is a nonhibernating animal started out

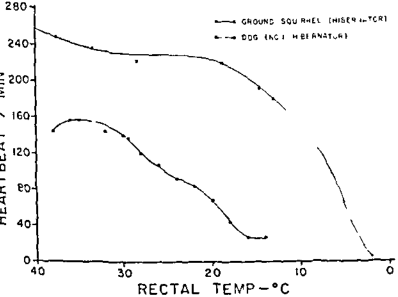

FIGURE 40 Heart rates of hibernator (Arctic ground squirrel) and homeotherm (hypothermic dog) to illustrate one difference between hibernation and hypothermia

with an initial heartbeat of 160, and rectal temperature of about 38°C At 15° heartbeat has fallen to 24, rectal temperature and asystole or ventricular fibrillation will soon occur This is the difference in one function between hibernators and nonhibernators

Dr Covino will speak about hypothermia, but I should now like to redefine hibernation *with one addition* *It is a profound physiologic* state, seasonal in nature—

Horvath Why do you use the word "profound?" What does it mean?

Hock It means everything, but I will leave it out There are very large changes, seasonal in nature in which the body temperature approximates ambient temperature and other physiologic functions fall to correspondingly minimal levels

In contrast, hypothermia is an accidental state The animal is not prepared for hypothermia, whether it be surgically induced, induced in the laboratory, or whether it be accidental He makes no preparation whatever for the state He only responds to it

I shall now sum up what I feel to be the important needs in the *continuing study of hibernation* *Despite the fact that there are 4,000* or so papers written on the subject over the last 400 years, there is still no very great knowledge of several important matters We know a great deal about the natural history of hibernation occurring in many mammals, insects, amphibians, reptiles, and so forth We know quite a bit about various phenomena during hibernation, both the physiologic, biochemical and so on We know almost nothing about the state itself I think this has been brought out in this discussion quite adequately

There are several important questions *to be investigated* *In the first* place, what is the cause, the stimulus for hibernation? Is it something like day length or is it a much more complicated matter, and is it different for each species?

The great problem is, what is the essential difference between hibernators and nonhibernators? Is there an essential difference? If so, is this a difference in the tissues, the cells, the enzyme systems, the hormonal control of the body or, perhaps, all of these?

This it seems to me, is the most promising avenue of investigation Until very recently there has been no attempt whatever made to investigate this particular question Perhaps in another 10 years we will have the answers But it seems to me that we now know enough about what constitutes hibernation—what are the phenomena that are exhibited during hibernation—to attack this central problem of what distinguishes a hibernator from a nonhibernator and on what level of organization?

mont Smith Could there be several relative differences, rather *the* essential difference?

ck Yes, there would be degrees of difference

mont Smith Degrees of difference of different kinds If there are il interrelated phenomena here, and if one changes profoundly e animal and another changes more in another animal, there is a ility and variability which is what you seem to find in your animal s

ck It is quite likely that not much difference will be found en a bear and any other homeotherm We may find profound ences in a ground squirrel and—

mont Smith It is possible, on this basis, that there is no single r in the hibernator which is completely absent in the nonhibernator, hat there are degrees, and these factors are grossly accentuated in ibernator and developed to a high degree, but can be found in ial form perhaps in the others

ck This is quite possible It is also possible that a hibernator may something, for example, enzyme systems that are a little different in the nonhibernator That might be why this curve of the differ between the dog s heart and the hibernator s heart showed such ences

mont Smith They do come down?

ck Yes, they do But it may be that there is a temperature point id which hibernators can function and nonhibernators cannot I this is the thing to look into at this time The basic difference een hibernators and nonhibernators is the fact that hibernators can on activities at a lower body temperature This may be simply a er degree of function at low temperatures, or it may be a very ent sort of function

ldes Do hibernators sleep in the active period? If so, is their ology during sleep different, say approaching that of hibernation nonhibernators?

ck Not during the real active period

ldes They don t sleep?

ck They do sleep but there is nothing different, apparently about during sleep This is quite well known In 1870 the French lemy of Sciences offered a prize for anyone who would find out undamental nature of sleep, so, quite a few of the great physiolo of the day did some fine work on hibernation, thinking to approach problem in that manner It turns out there is no similarity apntly Hibernation is not a profound sleep and the prize is still open

emont-Smith You say no similarity That wouldn t hold

Hock I should qualify and say that hibernation is not just a pro found sleep, it is much more than that

Montgomery More nearly a narcosis?

Hock That would approach it much more closely

Irving Part of our function here is observation of Arctic biologic phenomena, and many things we cannot explain However there is no apology needed for that, for you who live in temperate regions haven t yet explained all the physiologic phenomena of those areas

Fremont Smith Including sleep

Irving Yes I want to call attention to the fact that one of the significant points in hibernation is not probably the calorific provision in nutrition during the hibernating period but, much greater, bulk of water provision or escape from utilization of water, because water is always consumed for from at least one and perhaps ten times the weight of actual food which is burned

So far as I know, no one has considered explicitly the water require ment which is involved in hibernation or, what seems likely, the escape from the water requirements which we consider to be normal

I also would like to remark on another thing which these illustrations of Dr Hock s showed so well The very large population of ground squirrels in Arctic Alaska is maintained with a reproductive rate which is certainly no greater, and perhaps less than is common for similar species in milder climates Hence, the reproductive cost for the main tenance of Arctic population there, as can be seen in many other cases, is actually less than is the case in a temperate climate There is, then, in that particular area, no evidence that the Arctic situation imposes a particular stress upon the existence of populations There is a very reasonable view that the adaptive procedures outlined serve to obviate a stress and these animals in spite of the terrible Arctic climate in which they exist are living a peaceful, happy, economical life, more economi cal reproductively than were they in a milder climate

Where, then is the evidence for stress? There is a great deal of evidence that the perfection of adaptation obviates stress

Montgomery I should think hibernation especially useful in pre venting starvation

Irving Other animals are adapted to arctic life with their economy as favorable in respect to metabolism and reproduction as in the case among animals in other climates

Fremont Smith They have, or they wouldn t be here

Irving They have too much sense

Fremont Smith Or they would have died out Evolution has taught them how to do it

Behnke I think the same analogy holds for life at altitudes It is a most interesting adaptation There are glandular changes and other profound alterations, but once individuals have become adapted, they live normally at altitudes

Irving Without stress

Behnke And as easily as people do at sea level Feats of work, for example cultivating the slopes of the Andes have not been surpassed by comparable effort at sea level

Kark You are talking about man?

Behnke Yes May I ask a question? The hibernating animal is an animal that lives for a long time on a saturated fat diet his own fat Isn t that true? There are wide variations in weight reduction and subsequent weight regain Does the diet of the bears contain unsat urated fatty acid or saturated fatty acid? What is the condition of the blood vessels in these animals as you examine them? Is there athero sclerosis?

Hock I don t know

Behnke Who here has performed autopsies on these post mortem examinations on these animals?

Hock We have never looked into the blood vessels during autopsies

Fremont Smith Will you?

Hock Yes

Talbott You have a veterinary department They certainly must do something with the bears occasionally, or some of the native animals

Burch Some have been autopsied Atherosclerosis has not been found

Travell It is difficult to produce coronary atherosclerosis in the rat Sellers (45) has shown that when white rats are kept in an environmen tal temperature of 1° to 3°C for about a year over half of them have coronary atherosclerosis These of course are animals that are not accustomed to cold they don t hibernate This might be an important distinguishing characteristic in terms of stress on the coronary circula tion

In relation to the distinguishing features of the hibernating and nonhibernating animals I should like to ask about the temperature at which conduction in the peripheral nerves and other nerves might cease

Hock This has been done very nicely by Chatfield Lyman and co workers (46) It turned out that the peripheral nerves of the hibernator which was a hamster in this case conducted down to 2 C and that the rat which they were using as a nonhibernator stopped conducting at a temperature of 7 C Averages in both cases were 3 1° and 9 C

Travell Would this have anything to do with the temperature level at which the heart might cease beating?

Hock These were just isolated nerves However, the heart might still be beating

Fremont Smith This might well be a factor The hibernator may keep his heart beating at a much lower temperature, and presumably he needs some nerve conduction to do so

Travell Yes, to maintain the intrinsic control of the heart

Irving Years ago, John Tait, a former professor of physiology at McGill showed nicely, in a brief series of experiments, that there was a distinction between the temperatures at which the excised hearts of hibernating and nonhibernating mammals ceased to operate, it was quite a large difference

Hock What John Tait (47) found was that the isolated perfused heart of the hibernating woodchuck, in Ringer s solution, continued beating until freezing occurred

Hildes In the experiments you quoted about the nerve conduction, were the animals, at the time the nerve was isolated, in a state of hibernation or not, or have they compared the nerve conduction in the hibernating woodchuck with the nonhibernating woodchuck, rather than with a white rat?

Hock The experiment involved nonhibernating hamsters as an illus tration of potential ability of hibernators in contrast to rats

Talbott Have any blood studies been performed, blood sugar or urea concentration, as animals were leaving hibernation?

Hock Blood sugars have been done quite a bit In fact one of the older schools thought that the initiation of hibernation was an insulin phenomenon (48)

Talbott Has this been confirmed?

Hock No

Fremont Smith What about electroencephalography?

Hock That has been done by Kayser (49) and that is the only paper I know about

Fremont Smith How does it compare with sleep, do we know? There are rather characteristic changes as one goes into sleep It would be very interesting to know if similar characteristic changes happen on going into hibernation or during hibernation

Hock I can t recall If you like, I can answer that question later on but I cannot right at the moment

Editor's Note Dr Hock would like to add the following "afterthought" to his remarks at the conference

> Rohmer, Hiebel, and Kayser (49) studied the European ground squirrel as it awakened from hibernation They found a progressive increase in frequency and gradual increase in amplitude of electro-

Montgomery Do all true hibernators fail to shiver during the decrease of body temperature, and shiver during at least part of the rise of temperature, as far as you know?

Hock There is violent shivering when aroused from hibernation This is always true in my experience Going into hibernation is quite different in different animals, and it is quite hard to study entrance into hibernation, although Lyman (51) has done so successfully The ground squirrel is known to have a period of greater inactivity preceding hibernation For some days it will be lethargic, rarely emerging from the burrow Temperature is presumably very labile at this time The squirrel is very quiet and appears to sleep much prior to hibernation Johnson (34) has said that the thirteen lined ground squirrel goes into hibernation from a state of sleep In contrast, the hamster, as shown by Lyman,* has a sudden marked temperature drop in a few hours and hibernates I can't answer the first question about shivering during entrance into hibernation, but I do not believe that it occurs I should also think that in the case of the hamster with rapid precipitous temperature drop it must not occur

Montgomery They all shiver on the way up?

Hock Yes This apparently is the main source of heat generation during arousal It was formerly thought that the thermogenesis site was liver heart, or brain It appears to be true that the muscles are furnishing most of the added heat involved in warming

Fremont Smith Are you saying that whereas some other animals perhaps go into a good sleep before they hibernate the hamster just takes a cat nap?

Kark Captain Behnke left us feeling that man
but certainly, Monge (52),
the Peruvian civilization ha
man could not reproduce properly

Fremont Smith But there still are some men reproducing in the Peruvian mountains at over 12,000 feet, even though that particular race

*Lyman C P Unpublished

has deteriorated Some kind of adaptation seems to have taken place This is something Dr Sidney C Burwell of the Harvard Medical School is very much interested in A group may go to Peru, because they do not understand how it is possible for the fetus to be provided with enough oxygen at 12,000 feet to be able to live There are llamas and sheep in those environments which have become adapted The group is hoping to make a comparative study, to find out what this adaptation process is The very fact that there are groups of people living there and reproducing, and that they have been doing this for generations, shows, inadequate as it may be, that there has been a kind of adaptation, apparently quite an efficient one

Kark Not a complete one, not like the Alaskan ground squirrel which made a complete adaptation

Fremont Smith It depends upon what you mean by complete

Meehan This matter of adaptation should be viewed with respect to time required for evolution After all, our life span is very short, in terms of evolution

Burton We should not neglect the classical literature on this subject Though the scientific details may not be as well controlled and reported as we would like, there is a well known report of an actual case of hypothermia in a human, and it might even be true hibernation It is told in a poem titled, The Cremation of Sam McGee by Robert W Service * It originally appeared in about 1900 (53)

There are strange things done in the midnight sun
By the men who moil for gold,
The Arctic trails have their secret tales
That would make your blood run cold,
The Northern Lights have seen queer sights
But the queerest they ever did see
Was that night on the marge of Lake Lebarge
I cremated Sam McGee

Burton This is significant the origin of Sam McGee

Now Sam McGee was from Tennessee, where the cotton blooms and blows
Why he left his home in the South to roam round the Pole, God only knows
He was always cold, but the land of gold seemed to hold him like a spell,
Though he d often say in his homely way that he d sooner live in hell '

*Reprinted by permission from *The Collected Verse of Robert W Service* New York Dodd Mead & Co Toronto Ryerson Press and London Ernest Benn Ltd

On a Christmas Day we were mushing our way over the Dawson trail.
Talk of your cold! through the parka's fold it stabbed like a driven nail.
If our eyes we'd close, then the lashes froze till sometimes we couldn't see,
It wasn't much fun, but the only one to whimper was Sam McGee.

And that very night, as we lay packed tight in our robes beneath the snow,
And the dogs were fed, and the stars o'erhead were dancing heel and toe,
He turned to me, and "Cap," says he, "I'll cash in this trip, I guess;
And if I do, I'm asking that you won't refuse my last request."

Well, he seemed so low that I couldn't say no; then he says with a sort of moan:
"It's the cursed cold, and it's got right hold till I'm chilled clean through to the bone.
Yet 'tain't being dead—it's my awful dread of the icy grave that pains;
So I want you to swear that, foul or fair, you'll cremate my last remains."

A pal's last need is a thing to heed, so I swore I would not fail;
And we started on at the streak of dawn; but God! he looked ghastly pale.
He crouched on the sleigh, and he raved all day of his home in Tennessee;
And before nightfall a corpse was all that was left of Sam McGee.

There wasn't a breath in that land of death, and I hurried, horror-driven,
With a corpse half hid that I couldn't get rid, because of a promise given;
It was lashed to the sleigh, and it seemed to say: "You may tax your brawn and brains,
But you promised true, and it's up to you to cremate those last remains."

Now a promise made is a debt unpaid, and the trail has its own stern code.
In the days to come, though my lips were dumb, in my heart how I cursed that load.
On the long, long night, by the lone firelight, while the huskies, round in a ring,
Howled out their woes to the homeless snows—O God! how I loathed the thing.

And every day that quiet clay seemed to heavy and heavier grow;
And on I went, though the dogs were spent and the grub was getting low;

The trail was bad, and I felt half mad, but I swore I would not give in,
And I d often sing to the hateful thing, and it hearkened with a grin
Till I came to the marge of Lake Lebarge, and a derelict there lay,
It was jammed in the ice, but I saw in a trice it was called the Alice May
And I looked at it, and I thought a bit, and I looked at my frozen chum,
Then Here, said I, with a sudden cry, is my cre ma tor eum

Some planks I tore from the cabin floor, and I lit the boiler fire
Some coal I found that was lying around, and I heaped the fuel higher
The flames just soared, and the furnace roared—such a blaze you seldom see
And I burrowed a hole in the glowing coal, and I stuffed in Sam McGee

Then I made a hike for I didn t like to hear him sizzle so,
And the heavens scowled, and the huskies howled and the wind began to blow
It was icy cold but the hot sweat rolled down my cheeks, and I don t know why,
And the greasy smoke in an inky cloak went streaking down the sky

I do not know how long in the snow I wrestled with grisly fear,
But the stars came out and they danced about ere again I ventured near,
I was sick with dread but I bravely said, I ll just take a peep inside
I guess he s cooked, and it s time I looked , then the door I opened wide

And there sat Sam looking cool and calm in the heart of the furnace roar,
And he wore a smile you could see a mile, and he said, Please close that door
It s fine in here, but I greatly fear you ll let in the cold and storm—
Since I left Plumtree down in Tennessee, it s the first time I ve been warm

There are strange things done in the midnight sun
By the men who moil for gold
The Arctic trails have their secret tales
That would make your blood run cold,
The Northern Lights have seen queer sights,
But the queerest they ever did see
Was that night on the marge of Lake Lebarge
I cremated Sam McGee

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The trail was bad, and I felt half mad, but I swore I would not give in,
And I d often sing to the hateful thing, and it hearkened with a grin
Till I came to the marge of Lake Lebarge, and a derelict there lay,
It was jammed in the ice, but I saw in a trice it was called the *Alice May*
And I looked at it, and I thought a bit, and I looked at my frozen chum,
Then Here, said I, with a sudden cry, ' is my cre ma tor eum "

Some planks I tore from the cabin floor, and I lit the boiler fire
Some coal I found that was lying around, and I heaped the fuel higher
The flames just soared, and the furnace roared—such a blaze you seldom see
And I burrowed a hole in the glowing coal, and I stuffed in Sam McGee

Then I made a hike, for I didn t like to hear him sizzle so,
And the heavens scowled, and the huskies howled, and the wind began to blow
It was icy cold but the hot sweat rolled down my cheeks, and I don t know why,
And the greasy smoke in an inky cloak went streaking down the sky

I do not know how long in the snow I wrestled with grisly fear,
But the stars came out and they danced about ere again I ventured near,
I was sick with dread, but I bravely said I ll just take a peep inside
I guess he s cooked, and it s time I looked ', then the door I opened wide

And there sat Sam looking cool and calm, in the heart of the furnace roar,
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SOME OBSERVATIONS ON VENTRICULAR FIBRILLATION IN ACUTE HYPOTHERMIA

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AT THE FOURTH CONFERENCE ON COLD INJURY Dr Shumacker and Dr Lewis discussed many of the problems of hypothermia particularly as they related to cardiac surgery They pointed out at that time that the most pressing problem and the greatest hazard in hypothermia was high frequency of ventricular fibrillation

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surgery but ventricular fibrillation as it pertains to acute profound hypothermia uncomplicated by any surgical maneuver

At the outset I would like to describe briefly the methods (1 2) we used for inducing hypothermia since I think there is little doubt that the various methods used to induce hypothermia do have an effect on the incidence of ventricular fibrillation

As the dogs a e h e ght n a r l h —

I

is necessary to suppress shivering it is given The dogs are placed in a water tank the temperature of which is 5°C and their temperature is allowed to fall without any surgical intervention Artificial respira tion is started in all cases at a rectal temperature of 30°C and serum pH maintained at 7 3 to 7 5 so that our dogs are not markedly alkalotic or acidotic

Unless I specify to the contrary all of our experiments were carried out under these conditions From a consideration of Figure 41 we can get some indication of the frequency of ventricular fibrillation It is a

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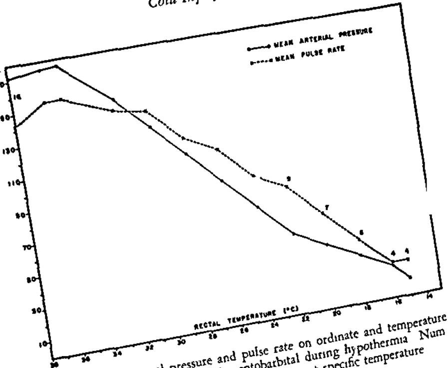

FIGURE 41 Mean arterial pressure and pulse rate on ordinate and temperature on abscissa in dogs anesthetized with pentobarbital during hypothermia Numbers above dots represent number of dogs surviving at specific temperature

simple graph of the mean arterial blood pressure and the mean pulse rate plotted against rectal temperature in degrees Centigrade At the start of cooling the figures represent the mean of sixteen dogs

As expected, during early cooling, there is a reflex rise of blood pressure and pulse rate, and then the two curves fall gradually But the important point is that there are sixteen dogs, at normal temperature, at the start At 24°C sixteen dogs are still alive But when rectal temperature reaches 22°C there are only nine dogs left, seven of the animals have fibrillated and died At 20°C, two additional dogs were lost from fibrillation When 18°C is reached, one more dog has fibrillated At 16° and 15°C, only four dogs remain alive out of the original sixteen Of these four dogs, one other dog fibrillated at about 15°C, and the remaining three dogs went into cardiac arrest at about 14°C

Ferrer Did any of these dogs go into atrial fibrillation?

Cotino No, I have very rarely seen atrial fibrillation in dogs There was none in this particular group So here are thirteen out of sixteen dogs developing ventricular fibrillation, and only three going into asystole

As is evident ventricular fibrillation occurs most frequently within a temperature range of 18° to 23°C rectal temperature

The question has come up as to why there is this high frequency of ventricular fibrillation in hypothermia Many have stated that the reason for it is that the hypothermic ventricle is more vulnerable to ventricular fibrillation The statement has been made that the actual ventricular fibrillatory threshold is probably lower As far as I know there is no actual proof of this

Again at the Fourth Conference on Cold Injury Dr Lewis stated that he and his group attempted to carry out studies of this nature and were unsuccessful We also have attempted to carry out studies on this and I believe we have been partially successful Our method of measuring the actual ventricular fibrillatory threshold in normothermic and hypothermic dogs has been as follows We use two square wave stimulators which are connected in tandem Stimulator No 1 is used to drive the heart at any frequency which we desire Stimulator No 2 then applies test-impulses to the ventricle at any point in the cardiac cycle This is done by means of having a variable delay circuit between Stimulator No 1 and Stimulator No 2

Electrodes then run from the stimulators and are attached directly to the ventricles The driving electrode is attached to the ventricle immediately below the atrio ventricular separation The testing stimulus is applied at the apex of the ventricle and is anodal in nature Its duration varies from 10 to 3 milliseconds Its intensity in our hands varies from 0 to 15 milliamperes The driving stimulus is kept constant So we can vary our testing stimulus from 15 to 0 ma and from 3 to 10 msec duration

The studies which we have carried out will be shown in Figure 42 We first determined the ventricular threshold itself that is we determined how much of a stimulus would be required to produce a single ventricular extrasystolic beat and took this as a measure of the basic ventricular threshold At normal temperature we have a period of absolute refractoriness during which stimuli of 15 milliamperes at 10 msec duration are not sufficient to produce a ventricular ectopic heat

At approximately 60 msec after the start of the QRS complex the ventricular threshold falls markedly to about 2 5 milliamperes falls gradually to about 1 ma rises slightly and then levels off during diastole at about 0 5 to 1 milliampere

If we carry out similar studies in the hypothermic dog we find this general pattern The entire cardiac cycle is prolonged because of intense bradycardia at 22°C The absolute refractory period is also prolonged markedly then there is the period of relative refractoriness during

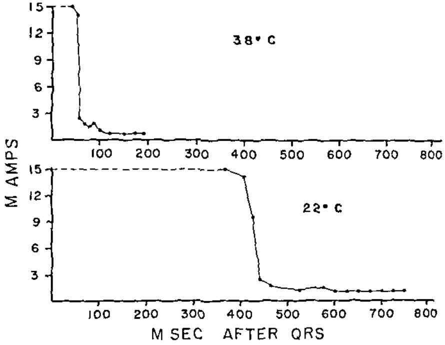

FIGURE 42 Comparison of excitability recovery curve at rectal temperatures of 38° and 22°C

which the threshold drops markedly, and finally diastole again with a threshold of about 1 milliampere

This is the type of study which we carried out initially We measured the ventricular threshold throughout the cycle first, then we went back, raised our stimulus from 0 to 15 milliamperes, increased our duration from 3 to 10 msec, and attempted to fibrillate these dogs

We found that with normothermic dogs we were unable to produce ventricular fibrillation using stimuli of 15 milliamperes and 10 msec duration, although in three cases we were able to produce multiple ventricular ectopic beats The multiple ectopic beats occurred when we used impulses of greater than 10 milliamperes, and they only occurred when we applied the stimuli during that portion of the relative refractory period which, I believe, corresponds roughly to the vulnerable period of Wiggers (3)

We cooled the dogs down to a rectal temperature of 30°C and carried out the same type of study At 30°C the picture was exactly the same as at 38°C We were unable to produce ventricular fibrillation

We then took the dogs on down to 22°C and repeated our studies and

found that in all dogs we were able to produce ventricular fibrillation when we applied stimuli to this portion of the cardiac cycle

Montgomery The refractory period was prolonged at 30°C ?

Cosmo The absolute refractory period, yes

Montgomery At 30°C ?

Cosmo Yes, but this is because of the bradycardia Figure 43 gives the mean ventricular fibrillatory threshold and diastolic threshold for eight dogs at normal temperature (38°C) and at 22°C A marked difference is apparent We find that at 38°C the mean diastolic ventricular threshold (hatched column) for the eight dogs was approximately 1½ ma The ventricular fibrillatory threshold (solid column) was greater than 15 ma We could not produce ventricular fibrillation

At 22°C the diastolic threshold [illegible]

ma in all eight dogs There is little doubt that there is about a fivefold increase, at least, in the vulnerability of the hypothermic ventricle to fibrillation

Hildes Could you comment a little more on the pH? You were careful to say you kept the pH between certain narrow limits I presume from this that you think this is important in the incidence of fibrillation

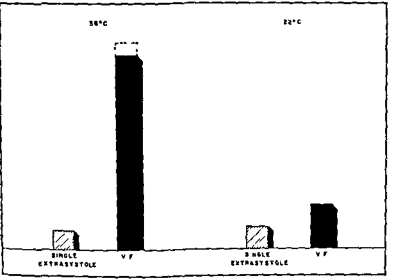

FIGURE 43 Comparison of mean diastolic and ventricular fibrillatory thresholds in the normothermic and hypothermic ventricle

COLMO Yes, I hope we can get into this a little later in the discussion

In casting about to determine what was responsible for this increased vulnerability of the hypothermic ventricle to fibrillation, it became obvious to us, as it has to many others that since these dogs are all anesthetized before being rendered hypothermic, it might be possible that the anesthesia was playing some role in this frequency of ventricular fibrillation

Therefore, we carried out a series of studies in which we used various anesthetic agents On Figure 44 we have plotted on the ordinate the per cent ventricular fibrillation under these various anesthetic agents

In the first group of fifty-four dogs, using pentobarbital anesthesia, we found that the incidence of ventricular fibrillation was about 92 per cent If we used thiopental, we found the incidence was reduced to about 55 per cent in a group of twenty-one dogs The conditions are the same in all of these categories

Using a small amount of thiopental, enough so it would not control the shivering, and then suppressing shivering with succinyl choline, in nine dogs we find the incidence of fibrillation is reduced to about 25 per cent Using cyclopropane, we find in eleven dogs the incidence

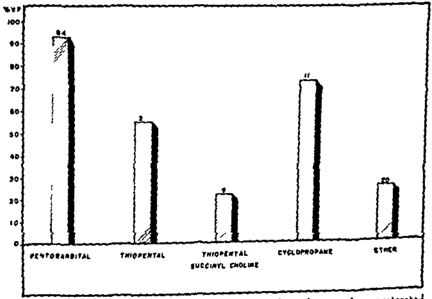

FIGURE 44 Frequency of ventricular fibrillation in hypothermic dogs pretreated with various anesthetic agents Numbers above bars represent number of dogs in each group

of fibrillation is about 73 per cent Using ether, we find in twenty dogs the incidence of fibrillation is about 25 per cent There is obviously a difference in the incidence of fibrillation as related to the anesthetic agent used prior to inducing a state of hypothermia

Whether this means that pentobarbital is acting in a negative fashion, that is, whether it is increasing the vulnerability of the ventricle to fibrillation, or whether these other agents are actually protecting the ventricle against fibrillation is difficult to state

Ferrer In discussing these studies, did you mention the incidence of cardiac arrest as well as that of ventricular fibrillation?

Cotino This is the incidence of ventricular fibrillation In other words, if 93 per cent went into ventricular fibrillation, the remaining 7 per cent went into asystole

Montgomery How hypothermic were the dogs?

Cotino The mean range of this group is about 18°C mean rectal temperature In other words, the range would be from about 15° to 24°C

Hildes Is there a difference in the temperature at which the pento barbital dogs died as opposed to the others?

Cotino Definitely The dogs in which the incidence of fibrillation is reduced will cool to lower temperatures So that in the dogs that were given thiopental, the mean rectal temperature at which death occurs would be down around 16° or 15°C, whereas in the dogs that were given pentobarbital, the mean rectal temperature would be around 18°C This we have done, compared the difference, and found it a significant one

Ferrer What physiologically, characterizes those dogs whom you have said die in cardiac arrest? Do they pass into a stage of electrical asystole or silence, or is there a gradual subsidence of the electrical impulse? What do you mean by the term *cardiac arrest*?

Cotino A gradual subsiding of the electrical impulse no indication of cardiac arrest

Ferrer This is important, because what you describe is quite a differ ent situation than that seen with electrical asystole or cessation of the electrical pacemaker I think the term *cardiac arrest* should always be clarified by a statement as to the mechanism whereby mechanical arrest takes place I am sure that a passage from ventricular fibrillation through a period of slow chaotic ventricular action to final electrical silence is quite a different phenomenon from a sudden cessation of the pacemaker

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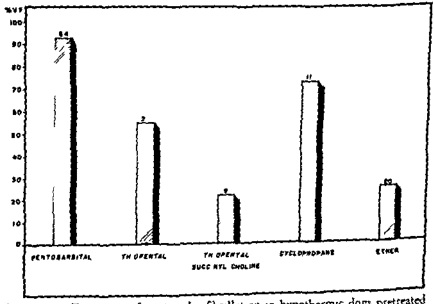

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Covino This is a very good point It has been confused in the '

ture Both cardiac arrest and electrical asystole have been used We should use the term *electrical asystole*

We next decided to do some studies on the relationship between cold acclimatization and ventricular fibrillation in hypothermia Earlier in the discussion we described how animals adapt to severe cold stress Later we will describe how human individuals adapt to severe cold stress

Taking a lead from some of the work of Dr Sellers (4) and Col Blair (5) who have shown very nicely that animals who are exposed to prolonged periods of cold are able to tolerate cold injury better than animals which are not previously cold exposed we decided to render some dogs hypothermic following varying periods of cold exposure

Figure 45 gives data on five groups of dogs The first group Group A were controls which were rendered hypothermic either during the summer season in Fairbanks or during the winter Prior to being rendered hypothermic in the winter they were kept indoors in heated

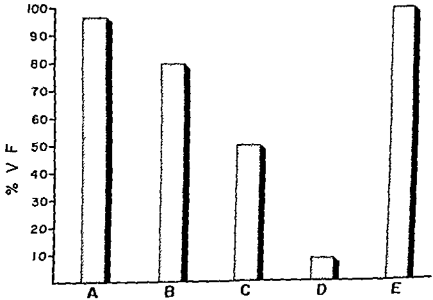

FIGURE 45 Frequency of ventricular fibrillation in unexposed and cold exposed dogs

Group A = unexposed
Group B = exposed for 1 week
Group C = exposed for 2 weeks
Group D = exposed for 4 weeks
Group E = exposed for 4 weeks and maintained indoors for 5 days

quarters for a period of about 2 weeks, the temperature of those quarters being between 23° and 27°C

As we pointed out in reference to Figure 44, the incidence of ventricular fibrillation was about 92 to 96 per cent

We then exposed a second group of dogs, Group B (Figure 45), to temperatures varying from 0° to −40°C for one week, and then brought them

a group of five

late, four did

Burton Is that statistically different from the other?

Cotino We have not analyzed it I don t think there are enough dogs in this series, and I would like to see more

Blair Was there any difference in the body temperature at which the dogs fibrillated?

Cotino That is shown in Figure 46 In the third category, Group C (Figure 45), we exposed four dogs to the same environment for a period of 2 weeks and found that two of the dogs fibrillated and two of them did not, the incidence of fibrillation being 50 per cent Again, I don t think there are enough dogs in this particular series, although it is inter

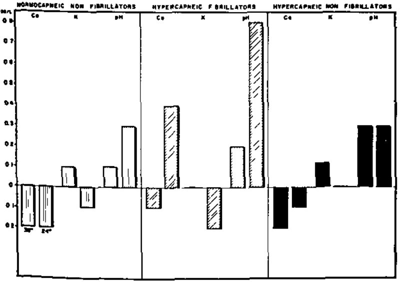

FIGURE 46 Coronary arteriovenous differences of calcium potassium and pH at rectal temperatures of 38° and 24°C in normocapneic nonfibrillating dogs, hypercapneic fibrillators and hypercapneic nonfibrillators

esting to note that in the control series there were twenty five dogs and only one did not fibrillate, in this series there are only four dogs, and two did not fibrillate So, I am sure if we add more dogs to this there will be a significant difference between these two groups

In the fourth group, Group D (Figure 45), we exposed eleven dogs to the same environmental temperature, varying from 0° to −40°C for a period of 4 weeks, and found that only one out of eleven dogs in this group fibrillated The one dog in this group which fibrillated, we found upon autopsy, had a ventricular catheter inadvertently left in his right ventricle We had been taking heart temperatures Some of the early work of Dr Hegnauer (6) shows that this is a powerful stimulus to ventricular fibrillation

Fetter Where was the tip of your catheter in the other instances?

Covino It was in the auricle in the other instances

In our fifth group, Group E (Figure 45), we exposed five dogs again to 0° to −40°C for 4 weeks, they were then taken into the heated quarters and kept there for 5 days We found that all five fibrillated So, apparently, after 4 weeks exposure to these temperatures there is a definite protective effect

If we just put the same group of dogs indoors for 5 days, they lose all this protective effect I think this agrees basically with the work of Colonel Blair and Dr Sellers who found that 4 to 5 days was sufficient time to deacclimatize animals So this is a technique by which we are able to reduce the incidence of fibrillation, and it may possibly explain some of the differences which various laboratories get

I have spoken to investigators from Miami and Georgia, and they claim all of their dogs fibrillated at all times of the year I know from my own experiences in Boston and from those of others who have worked in northern climates that the incidence of fibrillation is not always 100 per cent, but does vary So, this may be a possible explanation

Fremont Smith Are you going to talk about the possible mechanisms?

Covino No In these particular dogs we measured plasma potassium, plasma calcium, pH and blood sugar, and none of these differed from our control dogs The blood sugar levels remained constant in all groups of dogs The plasma potassium fell to the same level in all groups of dogs The calcium levels remained about the same in all groups The pH, as I stated at the outset fell from about 7 4 at normal temperature to about 7 2 at 30°C Then we turned on the artificial respiration and maintained it between 7 3 and 7 5

Fremont Smith Which anesthesia in the last series, did you use?

Covino This is all pentobarbital sodium

Fremont Smith That is the one that makes them the most susceptible?

Cosmo Yes

Crismon Were hematocrits measured in the various levels?

Cosmo In the control series they have been done many, many times Of course, they go up In the dogs exposed we did not measure

Burch Did you measure sodium?

Cosmo We have measured sodium in control dogs and it never seemed to change Table VI gives a summary of all five groups the control group, the group exposed to cold for 1 week, 2 weeks, 4 weeks 4 weeks plus 5 days indoors, it shows the number of dogs the number of dogs fibrillating, the terminal rectal temperature and whether there is statistically significant difference between the rectal temperature of these groups as compared to our control group

It is obvious that the group exposed for one week did have a significantly lower rectal temperature than the control group, in other words, they did fibrillate at lower temperatures

The group that was exposed for 2 weeks also had a significantly lower

TABLE VI

Comparison of Mean Rectal Temperature and Incidence of Ventricular Fibrillation in Unexposed Dogs and Those Exposed for Varying Periods to an Environmental Temperature of 0° to −40°C

	Control	1 Week Exposure	2 Weeks Exposure	4 Weeks Exposure	4 Weeks Exposure 5 Days Indoors
Number of dogs	25		4		4
Number of dogs fibrillating	24 (96 per				
Terminal rectal °C ± S	±				
P + Test					

temperature The group that was exposed for 4 weeks had a significantly lower temperature This would probably be down around 14°C except for one dog which had the catheter in the ventricle, and he fibrillated at 21°C

In the fifth group, the group exposed for 4 weeks and kept indoors for 5 days, the rectal temperature at which fibrillation occurred is the same as in our control group

Hildes The terminal rectal temperature of all the dogs in the group?

Covino Yes

Hildes Not the ones that just fibrillated?

Covino In this particular group, of course, there were four fibrillators Even if we omit the one dog that did not fibrillate, they had a significantly lower temperature than the control group

Hildes So that they fibrillate at a lower temperature?

Covino They fibrillate at a lower temperature, yes

Carlson Does the temperature in the heart differ in these experiments?

Covino Yes, it stayed within 2 to 3 degrees of the rectal temperature at terminus So in one case the mean heart temperature was about 20° or 21°C, and in another about 17°C

Ferrer What would be the difference in temperature between the right and the left heart in this, approximately?

Covino I don t know

Ferrer You are hyperventilating the dogs, and you are going to lose heat across the lungs

Horvath I don t know what this is

Ferrer I don t think anybody can say I think this is a fairly important variable Depending upon your heat loss through the lungs the left heart and, therefore, coronary artery, temperature of the blood may be quite a large variable and may represent a factor in these figures

[illegible] the dogs?

the lung There is no heat loss [illegible]

Dr H G Armstrong now Surgeon General of the USAF, and I, did this many years ago by putting a thermocouple in the pulmonary vein and artery and taking lung temperature Then we did the calculation If we had made the calculation before we had done the experiments, I don t think we would have done any If all of the heat required to saturate, and heat up the air were supplied by the lung circulation,

and not from up above, as it actually is, and calculating from the cardiac output how much change of temperature there would be, the fall in temperature would only be 1/20 degree In practice, we found animals breathing air at 40°F and then when switched to air at −40°F, showed no difference at all in the lung temperatures

This difference between the two sides of the lung, as Dr Horvath has shown, has something to do with the thermodynamics of the gas exchange in t [illegible]
circumstance [illegible]
normally It [illegible]

Horvath [illegible]
warming inspired air and losing heat would be partially through the bronchial circulation If there is any change in the relative volume of the bronchial circulation, you could add to the left heart a certain volume of blood which is fairly well cooled So, theoretically, you could change it some, I don t know how much This would depend on whether the bronchial circulation is being maintained or whether it is falling

[illegible]
get heat exchange across the alveolar surface but there is none there to speak of

Burch Was tracheal intubation employed?

Horvath Yes, and the statement is true even with tracheotomy We did that following Dr Burton s suggestion to us a long time ago When you measure the temperature as far as you can go down into the bronchioles, the temperature is always constant There isn t any heat exchange down below or, if there is any, it is very, very small

Burton Dr Covino do you feel this exchange in the properties of the heart muscle, must be mediated either by humoral agents or by the nerves? Because, after all, exposing the animals in the acclimatization to cold environment does not change the heart temperature It can t be a local response to it

Covino We have proof for that We did the same stimulation study on dogs which were exposed for 4 weeks Their ventricular fibrillation threshold is exactly the same as hypothermic dogs which are not previously cold exposed So, it is not any change in the ventricular musculature itself

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*The major exchange of evaporative heat loss with humidification and warming of the inspired air occurs in the nasal and laryngeal pharynx and the larynx Minor changes only are found to take place in the tracheal bronchiolar system

Burton You haven't yet cut the vagus?

Covino No, we haven t done any denervation studies or anything of that nature as yet As you say, I am sure it is caused by some humoral agent or some nervous factor

Next, I should like to discuss what role pH plays in the incidence of fibrillation in uncomplicated hypothermia

Horvath When you give an animal, especially a dog, one of the barbiturates, the pH drops to 7 2

Covino Not in the dogs we have used

Horvath That is interesting In all the other observations I have seen on this a pH around 7 2, 7 19, 7 18, and so on was reported

Covino In the last 5 years I have run through something like 500 dogs with pentobarbital The dog which has a low pH after being anesthetized with pentobarbital is the exception The pH is not 7 45, it may be 7 38 or 7 4 but certainly not as low as 7 1 or 7 2

Irving Why did you select that particular pH?

Covino I shall explain that when we discuss the subject of pH Around 1953, Dr Henry Swan (7) at Denver pointed out the importance of maintaining the pH constant in dogs which are being rendered hypothermic, particularly for cardiac surgery

We were interested in whether pH had some role in the production of fibrillation in dogs which were not subjected to surgical intervention but just uncomplicated hypothermia

We found that the incidence of fibrillation was about 90 per cent if we cooled animals allowed them to breathe spontaneously until such time as all resp [illegible]

but they were not anoxic

If we then took a group of dogs and artificially respired them from the start, so that their pH remained between 7 3 and 7 5 throughout the entire cooling procedure, the incidence of spontaneous ventricular fibrillation was reduced from about 90 per cent to about 20 per cent

We then inadvertently overventilated in a small group of dogs so that their pH s went up to about 7 7, 7 8, and all five dogs in this particular group fibrillated This was the reason why we have maintained this range of between 7 3 and 7 5, because it appears that, if you get above 7 5, you get about the same incidence of fibrillation, and if you get below 7 3 you get a high incidence of fibrillation

I think it was very interesting to note, also, that if we allowed these dogs to respire spontaneously down to about 30°C, so that their pH fell from about 7 4 to 7 1 or 7 2, and then started the artificial respira

tion and returned their pH level to between 7.3 and 7.5, they still had the same incidence of fibrillation at temperatures around 20°C. So it was our feeling that this fall in pH was acting as some sort of a trigger mechanism. It was not the pH itself causing the fibrillation but it was triggering some other mechanism which was causing the fibrillation.

Irving: Does pH 7.3 to 7.5 at 38° and 20°C mean the same thing?

Horvath: No. pH does change with the temperature.

Irving: And 7.3 is near neutral at 38°C but it is moved away from neutrality toward the alkaline side?

Montgomery: Were the animals all measured at the same temperature?

Covino: Yes, we measured them at the blood temperature. We measured the pH at 38° and at 20°C.

Fremont-Smith: You don't bring the blood up to 38°C?

Covino: No, we measure at the actual temperature of the blood.

Fremont-Smith: Then this error remains, doesn't it?

Irving: Not error.

Fremont-Smith: This differential.

Covino: There is an excellent study by Axelrod and Bass (8) who found that the fall in pH which would occur because of the cold itself would be very small, a fall from 7.4 to 7.35 at the most.

Montgomery: These are reported just as measured at the temperature?

Covino: Yes.

Montgomery: At the dog's blood temperature?

Covino: Yes. In view of some of the early studies on the relationship between pH and electrolytes, we felt that the low pH encountered in hypothermia might possibly cause some change in the electrolyte balance of the heart. So we proceeded to carry out some studies on the electrolyte balance of the normothermic and hypothermic myocardium.

We had three distinct groups of dogs, eight in each group. Figure 46 shows on the ordinate milliequivalents per liter for calcium, potassium and pH units.

In the first group we hyperventilated the dogs throughout the hypothermic procedure and their pH was maintained between 7.3 and 7.5; none of these dogs fibrillated.

In the second group we allowed the pH to fall from 7.4 to about 7.1 and all of the dogs in this group fibrillated. The third group were dogs whose pH again was allowed to fall from about 7.4 to about 7.1; none of the animals in this group fibrillated. When I state that one group of dogs fibrillated and one group did not, I do not mean that this was a group of sixteen dogs in which just 50 per cent fibrillated. We had to

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We were interested in whether pH had some role in the production of fibrillation in dogs which were not subjected to surgical intervention but just uncomplicated hypothermia

We found that the incidence of fibrillation was about 90 per cent if we cooled animals allowed them to breathe spontaneously until such time as all respiratory movements stopped, *and* then artificially respired them or actually hypoventilated them with room air or oxygen plus CO Their pH was kept at about 7 1 throughout the entire cooling procedure but they were not anoxic

If we then took a group of dogs and artificially respired *them* from the start so that their pH remained *between* 7 3 and 7 5 throughout the entire cooling procedure the incidence of *spontaneous* ventricular fibrillation was reduced from about 90 per cent to about 20 per cent

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work on a great number of dogs before we found eight that did not fibrillate

We measured sodium, potassium, calcium, magnesium, chlorides, and pH We measured these in the arterial system, and we also measured them in the coronary venous system

We found, with respect to sodium and magnesium and chlorides, there were no changes either at the normal temperature or at low temperatures in any of the three groups

We did find, however, that there were certain changes which did occur as far as calcium and potassium were concerned and that these changes could be correlated *with the incidence of fibrillation*

In this first group of dogs which were hyperventilated throughout the entire hypothermic procedure, at 38°C there was no difference between arterial and coronary venous calcium level This is a mean negative difference but, actually, if it is analyzed statistically, there was no difference Again at 24°C there was no statistical difference between the arterial concentration of calcium and the coronary venous level The same held for potassium, there was no difference at 38° or 24°C

In pH there was a slight rise in the coronary venous pH at low temperatures, but this is seen by most people, and these two were not significantly different

We then go over to the other group of nonfibrillators In this group the pH was allowed to fall, and yet they did not fibrillate Again we found the same thing, there was no significant difference between the arterial and coronary venous levels of calcium at 38° and 24°C, no *significant difference between the arterial and coronary venous potas*sium levels at 38° and 24°C and no difference between the pH in arterial and coronary venous blood

However in the group of dogs which fibrillated, at 38°C, there was, again, no difference between arterial and coronary venous calcium At 24°C there was a significant difference between arterial and coronary venous calcium, and it was a positive calcium difference, that is, the calcium in the arterial circulation was higher than the calcium in coronary venous blood It was higher by a mean of 0 4 mEq /l The range was from about 0 1 to 0 8 mEq /l It was a statistically significant difference

There was no difference in potassium between arterial and coronary venous blood at normal temperature At 24°C there was a negative potassium balance There was more potassium in the coronary venous blood than there was in the arterial blood This was statistically significant

The mean difference in pH at normal temperature was about 0 03 pH

units At 24°C the difference was approximately 0 08 pH units We found that in all of the dogs which fibrillated the pH in coronary venous blood at low temperatures was always 0 05 pH units, or greater than the pH in the arterial blood The dogs which did not fibrillate, whether they were hyperventilated or not hyperventilated, never showed a pH difference of 0 05 or greater, it was always below 0 05 pH units

So, we were faced with the situation in which we saw a positive calcium balance at low temperature in a dog which fibrillated We do not see it in the dogs which did not fibrillate And there was this tremendous increase in the pH difference between arterial and coronary venous blood

So, it appeared to us that in the dogs which were about to fibrillate, the calcium was shifting into the heart, potassium was leaving, and hydrogen ions were also apparently shifting into the heart

From some of the work carried out at normal temperature, on isolated hearts, one of the easiest ways to fibrillate a normothermic isolated heart is to increase the calcium going into the heart and increase the potassium going out

So we felt that we had some sort of a cause and effect relationship between calcium penetration of the heart and potassium exodus from the heart and ventricular fibrillation at low temperatures

Burch

Cotmo

ions are gc

Here at the Arctic Aeromedical Laboratory we carried out further studies on the relationship of electrolytes to hypothermic ventricular fibrillation We are coming to the point made earlier We did infuse potassium into the circulation of a number of dogs We found that, if we perfused enough potassium so that the potassium concentration was maintained between 4 mEq /l and 5½ mEq /l, we found no fibrillation This was in a group of about five dogs

If we overshot this mark and increased the potassium concentration of blood to above 5 5 mEq /l, we found either fibrillation or electrical asystole at high temperature Obviously, we were running into a problem of potassium intoxication If we did not infuse enough potassium to raise the potassium level to at least 4 mEq /l, then, again, we got about 90 per cent incidence of ventricular fibrillation We tried the converse We tried to reduce the calcium levels of blood by infusing EDTA (ethylenediaminetetraacetic acid), a chelating agent which is supposed to bind calcium We found, by infusing this agent, we could effect a reduction in the calcium level of the blood, and the temperature to which these dogs cooled was significantly lower

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From some of the work carried out at normal temperature, on isolated hearts, one of the easiest ways to fibrillate a normothermic isolated heart is to increase the calcium going into the heart and increase the potassium going out

So we felt that we had some sort of a cause and effect relationship between calcium penetration of the heart and potassium exodus from the heart and ventricular fibrillation at low temperatures

Burch Did you say the hydrogen ions were going in or out?

Covino It would appear they go in The pH goes up, the hydrogen ions are going down So you have less in coronary venous blood

Here at the Arctic Aeromedical Laboratory we carried out further studies on the relationship of electrolytes to hypothermic ventricular fibrillation We are coming to the point made earlier We did infuse potassium into the circulation of a number of dogs We found that, if we perfused enough potassium so that the potassium concentration was maintained between 4 mEq /l and 5½ mEq /l, we found no fibrillation This was in a group of about five dogs

If we overshot this mark and increased the potassium concentration of blood to above 5 5 mEq /l, we found either fibrillation or electrical asystole at high temperature Obviously, we were running into a problem of potassium intoxication If we did not infuse enough potassium to raise the potassium level to at least 4 mEq /l, then, again, we got about 90 per cent incidence of ventricular fibrillation We tried the converse We tried to reduce the calcium levels of blood by infusing EDTA (ethylenediaminetetraacetic acid), a chelating agent which is supposed to bind calcium We found, by infusing this agent, we could effect a reduction in the calcium level of the blood, and the temperature to which these dogs cooled was significantly lower

However we were able to reduce only the incidence of fibrillation from 90 per cent to 70 per cent by this procedure, even though we were reducing the calcium level from about 5 mEq /l to 3 mEq /l

In a small group of dogs, we made the observation that at low temperatures, despite the constant infusion of EDTA, we got a rebound phenomenon, such that the calcium level fell, as I say from about 5 mEq /l, at normal temperature, to about 3 mEq /l at about 20° or 22°C rectal temperature Below this temperature, the calcium apparently rose again It rose to about 5 mEq /l In some cases it overshot the mark and went up to as high as 7 mEq /l

It would appear that at low temperatures the EDTA is not binding the calcium and is releasing all that it has bound This may be the reason why our incidence of fibrillation was not reduced We have not as yet tried to administer potassium and also EDTA to see if we can completely eliminate fibrillation

Burch Have you completed that phase?

Cotino Yes

Burch It is known in clinical cardiology that ventricular fibrillation can be stopped, if you do not wait too long, by injecting potassium Sodium versenate which is a chelating agent for ionized calcium, will also help but is not as effective as potassium I would not be too sure that sodium is not playing a role in this Our methods are not sensitive enough to measure changes in sodium concentration which may be physiologically significant

Cotino We did measure sodium in the arterial system and coronary venous system, at normal and low temperature, and could see no difference This may have been the inadequacy of our method, however, but we did not feel it was worth while going on

The one thing we have not done is to take samples of ventricular muscle and actually determine the intracellular levels of potassium

Burch With radiosodium tracers, small changes might be detected

Cotino There is one brief study reported in the Federation Proceedings (9) several years back in which tracers were used with potassium and sodium tracers and it was found that there was an exodus of potassium from heart muscle but not much was found with respect to sodium

Crismon Did you make any attempt to find out whether manipulation of pH in normothermic animals made a change in the circulating calcium or its rate of replacement?

Cotino No, we didn t

Crismon It appears to me that pH should make quite a difference in

the accessibility of calcium from body stores, knowing the influence it has on solubility

Cotino I have little doubt that pH has definite effect on the ionizable calcium in the blood We have not done this

Hildes Dr Burch s remarks suggest to me that perhaps it might be useful to pretreat the animal by salt depletion and see whether that makes a difference Does that fit in with your idea?

Burch The situation is quite a complex one You may have seen the [illegible] Roberts and Man[illegible] (10) and others concerning [illegible] c, and the associated electro [illegible] closely interrelated that it is almost impossible to change one without changing one or more of the others

Carlson It is necessary to distinguish which are osmolar effects and which are specific ion effects

Burch Osmolarity must be only one factor

Carlson The relationship of sodium potassium and calcium is of [illegible] the action potential and potassium reduction lengthens it, pH seems to have no effect over a wide range

Burch Sodium might have an inverse relation to potassium

Carlson Are sodium and potassium linked due to water shift or by transfer mechanisms?

Burch I do not know what you mean by linkage We know there is an inverse relationship in exchange phenomena between sodium and potassium

Crismon Not one for one

Burch No

Crismon I think it is interesting that the rat, which is a nonfibrillator in hypothermia, can be made to survive and have spontaneous respiration and heart rate at 6° to 10°C deep body temperature, if you give infusions of calcium chloride, which is not what you would expect here Their hearts do not appear to be challengeable by calcium under those conditions

Fremont Smith Didn t Audrey Smith (11) get them down to the solid frozen state and resuscitate without infusion?

Crismon She achieved cardiac standstill

Fremont Smith This was even more severe than what you spoke of, and yet no infusion was necessary

Crismon Those animals were cooled by the Andjus (11) method which provides for a very high acidity owing to respiratory accumulation of carbon dioxide throughout the period That of itself, if the pattern is the same, contributes toward the maintenance of high ionized calcium in the plasma throughout that period

Covino As described at the Fourth Conference on Cold Injury, Dr Shumacker and a group (12) at Bethesda have shown that, with respect to hypothermic surgical ventricular fibrillation, this latter can be prevented by means of *infiltrating the sino auricular node with procaine* or denervating the heart, removing the sympathetic influence, particularly I wonder whether this may be true ventricular fibrillation resulting from hypothermia There have been some studies done on the denervated heart lung preparation, which is rendered hypothermic These hearts continue to fibrillate at low temperatures, despite the fact that they are denervated

I wonder whether this may be one of the situations where this procedure will protect the heart at moderate temperatures of hypothermia that is about 24°C, with cardiac surgery, but will not protect the heart at low temperatures without any cardiac surgery

So again, getting back to my original thesis, the situation may be different when there is moderate hypothermia plus cardiac surgery, and profound hypothermia without cardiac surgery, and it would appear to be the case in this particular instance

Ferrer What do you mean by cardiac surgery?

Covino Doing venous occlusion and ventriculotomy I think that *is the usual sham procedure done on animals* He also stated that with arfonad a sympathetic blocking agent which appears to me to be a very strange drug, he was able to reduce the incidence of ventricular fibrillation In one of our earlier works (1) we tried dibenamine and SY 21, a new and supposedly very potent sympathetic blocking drug and we were unable to alter the incidence of ventricular fibrillation There was still an incidence of about 90 per cent

Horvath Cookson (13) *got no ventricular fibrillation when he used* arfonad

Covino This is the only sympathetic blocking agent which apparently prevents fibrillation

Horvath He used dibenamine which has a different action than arfonad, and obtained the same results with that

Covino I wondered whether the arfonad reaction is not peculiar to the drug

Horvath It is not peculiar to the drug This reaction can also be obtained with dibenamine, which is entirely different

Covino It cannot be obtained with dibenamine We went through what we thought were the standard sympathetic blocking drugs, and using 20 mg /kg, we were unable to produce any marked beneficial effect

The problem comes up about whether the increase in venous pressure might be responsible for the incidence of fibrillation since arfonad does decrease the arterial blood pressure Again this was stated to be beneficial by Bigelow and some of the German workers (14,15) So, we did some studies in which we reduced the circulating blood volume of

These are little points of confusion, but I think they are important

Horvath Quite a few people have only been able to get 30 or 40 per cent, without hyperventilating, without controlling the pH, without doing any of these other things

Covino As I stated initially, there are many factors involved The acclimatization may be involved, the anesthetic agent used

I think it is important in speaking about ventricular fibrillation in hypothermia to define what is meant and to define the conditions, because it does make a difference

Carlson Is your point that doing the same procedure the percentage is not 90 but 30?

Horvath It is such a variation, it is hard to tell what these mean

Covino Actually using the pentobarbital anesthesia and not hyperventilating I can t think of any instance where the incidence was as low as 30 per cent, offhand

Horvath I am not sure

Covino Using this as standard procedure I don t know of any

Horvath I know somewhere it is 50 per cent

Covino I have had that experience, but never below

Fremont Smith Your point is that there is need for exact specifications of the conditions is it not?

Covino Yes

Fremont Smith This will apply across the board in many experiments, but in this complicated situation it becomes crucial

Covino Yes very crucial

Behnke What is the effect of vagotomy?

Covino Vagotomy has no influence on the incidence of fibrillation

Behnke Does it affect the heart rate?

Covino Very little, actually, at low temperature

Behnke Dr Crismon, isn t there a critical range of temperature even

in the rat? That is, did not Audrey Smith (11), in her experiments, lose rats at a certain range of temperature in cooling, between 15° and 20°C deep body temperature?

Crismon It is difficult to say because she was using the Andjus method of cooling (11) Animals were left in a sealed jar in the refrigerator and, when they were removed, the rectal temperature was approximately 15°C Furthermore, the rat heart does not fibrillate in hypothermia I don t think the comparison is easy between the two groups

Covino I think, however, your statement is true because if they don t fibrillate usually between a temperature of 15° to 23°C, all of our control dogs go into electrical asystole

Meehan In talking about fibrillation in terms of cardiac rhythm and cardiac surgery as practiced in humans, the situation in surgery can be complicated quite considerably by the amount of dissection that the surgeon does within the thorax You can disturb the various connections of the autonomic system in this area quite considerably just by the process of dissecting and freeing the structures that are to be repaired or altered This in itself can alter considerably the potential course of the patient

Ferrer In the small group that does not go into ventricular fibrillation but slowly declines the rate of impulse formation, does this remain a sinus pacemaker? Is there a P wave before every QRS?

Covino In about 50 per cent of the cases it remains a sinus pacemaker In the other 50, there is an atrioventricular block

Burch Have you examined the auricles to see if they contracted?

Covino No, I have not This is just from the electrocardiogram

Burch We administered potassium intravenously and produced "apparent" electrical asystole of the auricles, but they were contrasting in a peristaltic fashion Electrocardiographically there were no detectable P waves Obviously, there was electric activity not demonstrable electrocardiographically

Horvath This is true of mechanical activity When the chest is opened, the auricles are contracting

Ferrer Dr Covino was using only peripheral or limb leads in these experiments I believe atrial electrical activity may not always be apparent in these leads The proper way to check on the electrical activity is to place electrodes directly on the atrial wall Then it is possible to determine whether atrial fibrillation is present or not, a point as yet unknown in this range of temperature It is possible that the mechanical activity of the atria of which Dr Burch and Dr Horvath spoke might not be a result of intrinsic atrial contraction, but might occur as a result

of regurgitation through the atrioventricular valves during ventricular contraction This occurs in atrial fibrillation and some forms of A V nodal rhythm, for example Are you sure the atrial event precedes the ventricular?

Burch I am certain there was independent auricular activity It was not a passive phenomenon

Ferrer I think it is important to point out that we really don t know the cardiac mechanisms or rhythms occurring in these animals and humans at these low ranges of temperature I think we *should* know this, because there is something obviously different about this small group If they can maintain sinus pacemaker activity all the way down the temperature decline, this is an important lead

Fremont Smith Are you also saying that unless there is an atrial lead it is not possible to know whether there is real standstill?

Ferrer Are you speaking about atrial mechanical standstill?

Fremont Smith Yes It wouldn t be possible to know that it is a genuine standstill

Covino I am calling it electrical asystole

Fremont Smith That only means electrical from where the leads e taken We don t know if the animals have a mechanical standstill

Covino We have done a small number of studies on the isolated rabbit heart where we have cooled the temperature of the heart In the experiments we have done so far these hearts do not fibrillate They go into electrical asystole at about 15°C and they continue to have sinus pacemaker activity right down to 15°C

Fremont Smith Mechanical standstill too?

Covino What do you mean by mechanical standstill?

Fremont Smith I mean the distinction we have been making between mechanical standstill and electrical standstill

Burch It was mechanical contraction of the atrial muscle

Covino They both go out at the same time of course

Crismon I would like to point out that both Dr Shumacker (16) and Dr Lewis (17) have good evidence that in hypothermic animals tested during the opening of the chest where they were actually doing cardiotomies the heart was quiet Dr Shumacker s first accidental example occurred when he used citrated blood He commented on the absence of contractions specifically, and Dr Lewis did also in his report

Montgomery Did the isolated rabbit heart always regain its rhythm when the temperature was increased?

Covino Yes we could keep it down there The longest we did was about 15 minutes

Fremont Smith Inevitably?

Covino No We could rewarm, and it would continue to start beating again perfectly fine, no fibrillation This may be a species difference We were interested in this and began to cool some intact rabbits Out of a small series of five we have done so far only one of those fibrillated

Crismon It is probably a tribute to the excellence of your perfusion medium

Fremont Smith Maybe you didn t have any pentobarbital

Montgomery Dr Orville Horwitz had the same experience with the chilled isolated heart of the rabbit it does not fibrillate It resumes beating on rewarming

EDITOR S NOTE Dr Montgomery would like to add the following afterthought to his remarks at the conference

Horwitz and Peirce* were studying the effect of cold on the isolated perfused rabbit heart They measured coronary flow and by polarography perfusate and fluid recovered oxygen utilization The temperature range was 5° to 40°C They shifted temperature in both directions The coronary flow was maximum at temperatures between 27° and 29°C minimum at 5° to 15°C Oxygen utilization was maximal at 40°C and minimal at 5° to 15°C At the lower temperature ranges both coronary flow and oxygen utilization were reduced to less than 25 per cent of the maximum

Covino I am not sure whether you can take this as proof that cause of fibrillation in hypothermia is of nervous origin or humoral origin This may be a completely different situation

Dr Beavers has been working with me at the Arctic Aeromedical Laboratory and has some extremely interesting results obtained in using glycine in hypothermia

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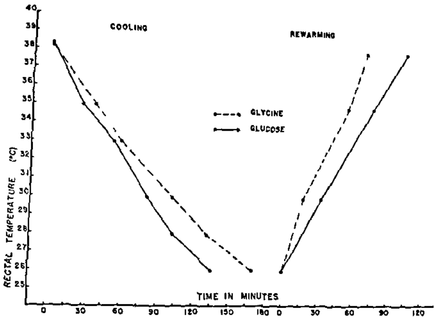

FIGURE 47 Reprinted by permission, from Beavers W R, and Covino, B G Immersion hypothermia effect of glycine *Proc Soc Exper Biol & Med 92, 319 (1956)*

Figure 48 is a demonstration of heat production in calories /kg /hr of the two groups

Burton How is the heat production calculated?

Beavers By the method of Weir (3) The glycine infusion was started 15 minutes prior to immersion There was an increase in heat production, as shown, which was attributed to glycine, and which was present from normal temperature down to 28°C rectal temperature Below 28°C, glycine did not appear to increase oxygen consumption The same is true during rewarming, in determining the oxygen consumption and heat production At 30° and 35°C we see an increase During cooling, the differences in heat production were statistically significant, however, during rewarming, the differences did not attain significance which we feel was because of the fact that during rewarming the animals who had received glycine were changed to glucose and vice versa This procedure probably blurred differences in heat output seen more sharply during cooling

Montgomery Was the caloric amount of glucose the same as glycine?

Beavers Yes We felt we had to do that We couldn t attribute to this any particular effect of glycine, otherwise We were stimulated in

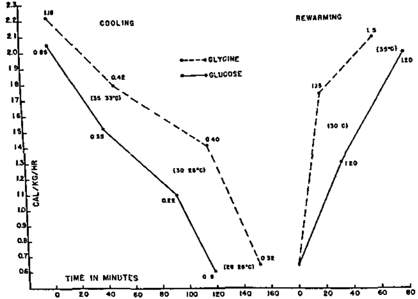

FIGURE 48 Reprinted by permission from Beavers W R and Covino B G Immersion hypothermia effect of glycine *Proc Soc Exper Biol & Med 92, 319 (1956)*

our interest in glycine by this first effort Later we found that glycine had been used as an antifibrillatory agent Since we found it had been easily tolerated by hypothermic animals, we decided to utilize the same compound to determine its effect on fibrillation both spontaneous and that which is induced in the hypothermic animal, which is surgically insulted by ventriculotomy at 25° to 24°C rectal temperature

Table VII is a comparison of ventricular fibrillation in glycine treated and control animals As Dr Covino mentioned we have to state under what conditions these animals are These are all pentobarbitalized animals artificially respired below rectal temperatures of 30°C In the control series we had 96 per cent fibrillation These are the animals which were cooled to either electrical asystole or to fibrillation The temperature at which the control animals were seen to terminate was 18 6°C In the glycine treated group of ten animals there was no fibrillation The average rectal temperature at which asystole occurred was 16 4°C This is a significantly lower temperature for termination

TABLE VII

Comparison of Frequency of Ventricular Fibrillation and Terminal Rectal Temperatures in *Treated and* Untreated Hypothermic Dogs

	Control	Glycine	Glucose
Total number in series	25	10	4
Number fibrillating	24/25 96 per cent	0/10 0 per cent	4/4 100 per cent
Terminal rectal temperature $\bar{x} \pm S$ °C	18 6 ± 0 88	16 4 ± 1 56	18 1 ± 1 8
P + test*		< 0 01	> 0 5

*Statistically significant when 0 05 or less Refers to comparison with control dogs

as was glycine as far as calories were concerned All of the animals fibrillated at an average temperature of 18 1°C, essentially the same level of temperature as controls

Table VIII is a comparison of the incidence of fibrillation in glycine treated and control hypothermic dogs subjected to cardiac surgery Of fourteen control animals cooled to a rectal temperature of 24°C and subjected to right thoracotomy, right ventriculotomy, and 10 minutes total venous occlusion, 93 per cent fibrillated Of eight dogs that received 5 per cent glycine (0 8 gm /kg) and were subjected to an identical procedure at 24°C, only one fibrillated The others were successfully rewarmed and survived at least 48 hours

A third group of dogs also receiving glycine were cooled to rectal temperatures of 18 5°C and thoracotomy, right ventriculotomy, and 20 minutes total venous occlusion were performed Three of these six animals fibrillated No attempt was made to rewarm survivors

TABLE VIII

Comparison of Incidence of Ventricular Fibrillation in Treated and Untreated Hypothermic Dogs Subjected to Cardiac Surgery

	Control	Glycine	Glycine
Total number in series	14	8	6
Rectal temperature of surgical procedure	24°C	24°C	18 5°C
Number fibrillating	13/14 (93 per cent)	1/8 (13 per cent)	3/6 (50 per cent)
Chi²*		< 0 01	

*Statistically significant when 0 05 or less Both glycine groups were added together and compared to control group

Glycine was found to diminish markedly the incidence of fibrillation in dogs subjected to hypothermic cardiac surgery

We were interested in the possible mechanism by which these animals were resistant to fibrillation We determined potassium and glucose blood levels in these animals, and the results are shown in Figure 49 which represents blood sugar levels in milligrams per cent In the glycine treated animals, there was a rise in blood sugar as cooling progressed There was no difference in the blood sugars of the control animals Figure 50 represents potassium in milliequivalents per liter Both the control and the glycine treated groups had lower potassium levels at a rectal temperature of 30°C However as cooling progressed in the glycine group, the potassium levels rose in contrast to the untreated animals whose potassium levels were even lower at 25° and 20°C

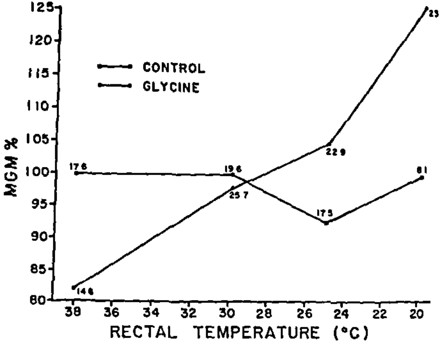

FIGURE 49

There is some work concerning intravenous administration of glycine done by Petersen (4), in which there is attributed to glycine the ability to produce glycogenolysis and, hence, elevate the blood sugar levels These data, indicating increases in blood sugar and plasma potassium levels with glycine infusion, are interpreted as being compatible with the concept that glycine produces an increase in glycogenolysis We feel that glycine was protective against ventricular fibrillation due at least partly to its ability to increase serum potassium levels

There has been some recent work to indicate that glycine increases the blood ammonia levels This is true of levels which are much higher than those which we infused which were in no case higher than 2 gm /kg But it is an interesting possibility that some of this protective action may be due to small amounts of blood ammonia which are produced by glycine

Montgomery May I ask whether any of the dogs with glycine, all of which went into electrical asystole, survived?

Beaters The nonsurgical series were terminal experiments We made no effort to rewarm them

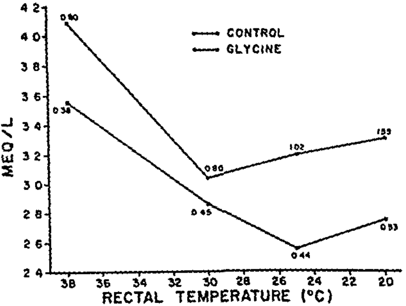

FIGURE 50

Montgomery Isn t it important to find that out?

Beaters Yes, we have done rewarming experiments which were successful We have rewarmed animals which have gone to asystole at 18° to 19°C levels

Montgomery Have they all survived?

Beaters Several survived at least 12 to 24 hours

Montgomery Your implication is that this is a possible therapy is it not?

Beaters Yes

Montgomery Isn t it essential that part of the experiment be that you see which animals survive?

Beaters We hope to do that We have not been well set up, actually, to rewarm the animals It takes perhaps 6 to 8 hours to cool them down to asystole, and a couple of hours to rewarm them With the nursing facilities available to us for instance we have run into trouble with rewarmed animals for which we did not have adequate care This is very important to do and I hope, as we continue, we will be able to do it

Cosmo We have some studies on glycine which we used during hypothermia and did some cardiac surgery at about 24°C These ani

mals were then rewarmed and maintained for at least 24 hours and, in some cases, a week, and there were no adverse sequelae

Montgomery Was any other material used that gave the same specific dynamic action, quantitatively?

Beaters Dinitrophenol has been used To my knowledge, there has been no other thermogenic agent tried

Travell What was the dose of glycine?

Beaters In the animals which I showed you here it was 1½ to 2 gm /kg in a 5 per cent solution, which was given intravenously, as they cooled In the animals which were rendered hypothermic and surgery was performed, there was a slightly smaller dosage, from 0 8 to 1 2 gm /kg The amount of heat effect from intravenous glucose which we used as control was not great We didn t determine any considerable difference between those which were cooled with glucose and those which were just cooled without any

As I understand the specific dynamic effect which is attributed to various food substances, protein has the highest, 30 per cent SDA (specific dynamic action), fat and carbohydrate have very much lower SDA I believe if it could be attributed to a meal, most of the SDA comes from the protein content of that meal

Horvath How many calories do you think you are getting from this? You are giving 2 gm /kg , your dogs weigh 15 kg That is 30 gm or approximately 120 calories Thirty per cent may be due to SDA Therefore, that is one third You are adding a total of 40 calories of heat How much heat are you extracting from the dogs?

Beaters When the animals had a skin temperature which was equivalent to that of the water and when the calculation was on a 0 6, 0 4 per cent of rectal and skin, the difference between the heat content at a given point in time of the two groups of animals was approximately 14 2 calories (Table IX) There was a 14 2-calorie difference As you mentioned, the maximum that could be obtained from the SDA effect of glycine was upward of 30 to 35 calories

Travell Glycine is a precursor of creatine, which is intimately concerned with muscle metabolism Heart muscle is rich in creatine Glycine effects would not necessarily depend on a calorigenic action Have you done any experiments injecting creatine rather than glycine?

Beaters We have the isolated heart set up One of the things that we wish to do is to study some of the metabolic compounds, those which are related to glycine and other food substances, to see what effect we can have on the isolated heart We have not done such a study yet

Drury You don t know what happened to the glucose If it formed glycogen you would actually require additional energy to synthesize the

TABLE IX

Method No 1

Caloric content = mass × specific heat × mean body temperature

Caloric difference = mass × specific heat ×
[temperature (glycine) temperature (glucose)]

Mass for both groups = 15 8 Specific heat = 0 83

Mean body temperature = 0 6 × rectal temperature + 0 4 × skin temperature

Therefore, caloric difference = 15 8 × 0 83 × 0 6 (27 8 26 0) = 14 16 cal

Method No 2

Caloric difference = total caloric expenditure (glycine) total caloric expenditure (glucose)

Caloric difference = 40 9 calories - 28 5 calories = 12 5 calories

glycogen The glycine, on the other hand, could have been burned directly

Beaters Dr Todd (5), one of our contractors, has found just that, that fed glycine actually increases during cold exposure, the glycogen content of rats, that is, those animals which are cold exposed and do not receive glycine have a lower glycogen content in their liver than do those which have received glycine This he feels, and with good reason, indicates that glycine increases glycogen storage However, as I mentioned earlier, Petersen (4), in rabbits given intravenous glycine, has found a decrease in liver glycogen levels These findings appear to disagree, however, they may be parts of a cycle Glycine either in itself or by a stimulating action may increase the two carbon fragments syn thesis to glycogen and also stimulate glycogenolysis

Drury I am thinking of the opposite Glycogen has a higher energy content than glucose You have to add energy to glucose to convert to

glycogen but you don't know what the liver glycogen was, for example, in these animals

Beavers We do not have those data on these animals

Drury There is always the possibility that glucose might have been going to glycogen and the glycine might not have been

Burton Aren't we making a mistake to concentrate too much upon the SDA aspect and the energy aspect? As far as you have gone, it might be nothing to do with that, until you have shown that alanine, phenylalanine, cystine do it, and so on It might be much more related to specific effect of glycine on the potassium

Beavers That is the interpretation we have now, that these are separate phenomena, that glycine is able to increase heat production which we found earlier, but that its effect in reducing the incidence of fibrillation we interpreted as due at least partly to its elevation of serum potassium levels

Fremont Smith Did you say you always pretreated, you started the glycine infusion sometime before?

Beavers Approximately 15 minutes

Fremont Smith Do you have a particular reason for doing it? Did you find it didn't work, if you didn't do it?

Beavers I suspect it would have worked if we had begun at the moment we placed the animals in the water

Fremont Smith You didn't test whether you could start a little while later and catch up with the situation?

Beavers No it is as we presented here

Cotino Speaking in reference to the fibrillation or the effect of reducing the rate of cooling?

Fremont Smith No, on fibrillation

Cotino You can start that later

Fremont Smith You can start it later and protect against fibrillation?

Cotino Yes

Burch Have you tried molar lactate solution on the basis of Dr Bellet's (6) study?

Ferrer How completely has that been confirmed Dr Burch?

Burch I do not know It appeared to be effective in isolated cases

Ferrer Were your own data A V block cases or supraventricular tachycardia?

Burch Ventricular tachycardia

Behnke Dr Beavers did you state that you thought perhaps elevation of the blood ammonia had a beneficial effect?

Beavers We stated there may be some slight increase in ammonia levels, and we have no information as to whether this does affect the

incidence of fibrillation In other words, this is an occurrence that may be taking place We prefer to interpret the protective effects as due to the elevation of serum potassium, but this has come to our attention

Behnke I was thinking that possibly the ammonia might have an adverse effect in that if you gave arginine, it would have beneficial effect Wouldn't it be of some interest to administer a little ammonia?

Beavers Yes

Behnke The other point I should like to bring out on the nutrient side is the possible difference between the chronic exposure to cold and the acute exposure If I recall correctly, as a result of chronic exposure, the heart will not tolerate the low temperatures to which it can be brought down, if it is cooled rapidly It would be of interest to prolong your experiments over a period of many hours of slow cooling, to see if there was a difference

It might well be that the level at which fibrillation takes place is much higher after the prolonged exposure A glib explanation of one of the reasons why the heart is more apt to fail in the chronic exposure was based on the nutrient idea

Beavers You are referring to human experiments?

Cosmo You are thinking of long term hypothermia, not cold exposure

Behnke I meant to say I am not speaking of acclimatization taking place previously, I am talking about the exposure of the dog, duration of exposure in the cold water

Burton The rate of cooling of the heart?

Behnke Yes

Montgomery Would you give us the dose?

Beavers It was 1 5 gm /kg

Montgomery Was that per hour?

Beavers That is the total dose

Montgomery Over what period of time?

Beavers Over the time it took to cool them, in this case approximately 150 minutes, 2½ hours

I might add we have extended the glycine studies to humans in cold exposure Gubner (7) in 1947 gave a dose of 20 gm of glycine to

glycine during cold exposure would increase heat production in man

Horvath It goes way back beyond Gubner

Montgomery It goes back beyond World War II

Fremont Smith Will you also tell us whether glycine given this way will have an effect on coronary flow?

Beavers This is in hypothermia?

Fremont Smith In any case

Beavers There is an Italian article (8), which we just recently acquired, that shows that in the isolated heart in hypothermia there can be coronary dilation with small amounts of glycine and constriction with greater amounts

Fremont Smith The direct beneficial effect of glycine on the supply of oxygen to the heart is conceivable

Beavers The dosages that the author used, as I recall, since he was infusing isolated heart, were much in excess of those which you could calculate that we were arriving at, but this is a possibility

Horvath You give 600 ml, you must have given at least 600 ml of fluid at the rate of 4 ml/min to the animal Don't you think that volume of fluid is doing something to that animal?

Beavers That volume was also given to the ones receiving glucose and had no effect

Ferrer In your over all plan for this, if I have it correctly in mind, it is your wish to try to achieve low levels of hypothermia in the intact dog for the purpose primarily of studying the central nervous system implications If you are able to protect your preparation completely, have you stopped at any very low and presumably desirable levels and maintained slow bradycardiac heart rates of sinus origin? Have you maintained circulation at that level?

Covino In some of the early work with Dr Hegnauer* we were able to take dogs down to 17° and 18°C, maintain them for an hour or so, with heart rates of 5 or 10 beats per minute, and then rewarm them without adverse effects We have never gone much into the phase of real prolonged hypothermia of 12 or 24 hours

Ferrer If you went down lower, you would get slower heart rates Then, presumably, the circulation would become inefficient Is this a proper assumption?

Covino No, I don't think the circulation is inefficient because, actually the metabolism of the dog has decreased so markedly that whatever circulation there is is sufficient to maintain him

Ferrer I bring it up because there is a possibility of controlling the heart rate externally, as you know

Covino Yes

Ferrer Would this be a desirable feature in your plan?

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*Covino B G and Hegnauer A H Unpublished data

Covino No, this would not be a desirable feature There is some work of Berne s (9) that shows if you take dogs down to about 20°C and artificially maintain the heart rate at, say, 20, 30 or 40 beats per minute, this is the easiest way to fibrillate the dogs

Ferrer How about further down where you might be interested? Would it be of any benefit to the circulation further down to keep the animals at 12 per minute?

Covino I think you are going to be taxing the heart if you increase the heart rate over and above its own spontaneous rate Just 12 per minute may not be bad, if you go from its own rate of 5 per minute up to 20 per minute, you are overtaxing

Ferrer I wonder if you have any wish in the dog experiments to control externally the rate of impulse formation Such a thing is available through the external pacemaker as you know This is a possible additional variable that you might wish to add some time

Covino I am not sure what the logic is behind this Are you thinking of trying to reduce the temperature further, or to maintain it at a steady rate

Ferrer Reduce the temperature further but maintain the animals at the same heart rate

Covino This is an interesting approach My own feeling is you are going to run into greater frequency of fibrillation, if you attempt this

Burton We have evidence to the contrary, even at lower temperature than this, we do not have evidence that the circulation, small as it is, is inadequate Evidently anoxia of the tissues is not a factor So I don t quite see why you would hope, by increasing the heart rate and increasing the circulation, to have any better results

Covino I agree I think most of the evidence is just the opposite The circulation is quite adequate at low temperature and low heart rates

Fremont Smith However, then you argue the other way Perhaps you should slow the heart rate, which would be beneficial It would seem to me the question that has been raised of experimentally moving the heart rate in one direction or the other and seeing what this did is a perfectly valid approach

Covino This has been done in certain cases It depends upon what you are seeking the low temperature for If you just want it for cardiac surgery [illegible]

means of surface cooling, and if you don t have heart rate, this is extremely difficult to do

Burch Potassium is used to produce solutions for bringing on asystole

Covino You are not speaking of Swan s group now?

Burch No our group and many others

Behnke One could slow the heart rate by using oxygen, perhaps As brought out here I think the heart rate is so adjusted to the oxygen requirement of tissue you don t like to do anything about it Is it correct that oxygen was not beneficial?

Covino I have used 100 per cent oxygen It doesn t seem to have much effect on the heart rate

Behnke With high CO_2?

Covino I have used 5 per cent CO_2 Lewis (11) used up to 10 It is the pH that is important not whether you are using high CO_2 or low CO_2 or oxygen or air

Behnke The liver isn t functioning and metabolism is falling

Covino Yes At 20°C you have 25 per cent of normal metabolism That is an interesting approach I haven t thought about it

Hypothermic surgical ventricular fibrillation differs from hypothermic ventricular fibrillation alone We have used ambonestyl, which is a pyridine derivative of procaine amide, as an antifibrillatory agent When we lower the body temperature of dogs to 24°C and perform thoracotomy and ventriculotomy along with venous occlusion we have no fibrillation However if we only cool the dogs down to below 20°C the incidence of fibrillation is about 30 or 40 per cent So here in one case it is apparently beneficial and in the other it is not

Beavers We might say the use of hypothermia in other conditions than cardiac surgery has been indicated in the last few years There has been a lot of work to indicate it might be useful in neurosurgery Some studies have indicated that in hemorrhagic shock, hypothermia is helpful although this is in doubt Therefore if there is going to be a use for hypothermia in other than open chest procedures approaches of protecting the individual against fibrillation, which do not involve procedures as have been mentioned in the Fourth Conference on Cold Injury (12) that are useful only with an open chest should be explored This is in the realm that we have been working

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HUMAN ACCLIMATIZATION TO COLD

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THE DIFFERENT ASPECTS of human acclimatization to cold are of particular interest to us here who are concerned with the study of factors affecting the health and combat efficiency of military personnel in arctic fields of operations

In view of the changing concepts of Air Force global strategy, we may expect to see an increase in the Air Force arctic endeavor This will place greater emphasis on the human factors Experience has shown in arctic operations that success or failure will depend upon human factors in general, and human tolerance to cold exposure in particular

For the accomplishment of the mission, this laboratory has five functional departments engaged in active research in the fields of environmental medicine, human and comparative physiology, biochemistry, psychology and human engineering and finally, a department which serves the function of transferring the research acquired facts and principles into items or techniques immediately useful to the Air Force Our intramural research and development program is augmented by university research contracts and consultant service

Under the general heading of environmental physiology, we have various teams working on different aspects of cold weather physiology, including human acclimatization to cold We are also concerned with the field thermal balance studies, under a great variety of conditions, including variations in heat production, and the different avenues of heat loss, etc We are also concerned with the endocrine functions and changes in peripheral circulation and, indeed, the significance of physical fitness in cold tolerance and the actual energy cost of various activities under different arctic conditions

In addition to our program here, similar studies are now in progress in the Antarctic where we have a small field laboratory established for this purpose The unique feature of this setup is that we have access to

*Present address Director of Research Lankenau Hospital Philadelphia Pa

achieve conservation of body heat by *effective vasoconstriction*, in addition to receiving heat from the small fires which are surrounding them while sleeping This is something we will come back to later

I should like to point out that it is quite conceivable that their ability to tolerate reduced skin and body temperatures may be the result of accustomization to this kind of life

I may add that during my recent trip to the South I was able to gather further information from a Mr Dalton,* who spent many months with these people Apparently they are still living there under extremely primitive conditions, roaming around the McDonald Mountains in the interior, not in the mountains themselves but in the valleys where the climate is rather warm and dry during the day and cold at night They are extremely primitive wearing no clothing whatsoever and having no modern utensils or tools or weapons of any kind They use the boomerang to kill whatever they can They are skinny and tall At night they sleep nude on the ground, unprotected The only thing they do is to construct what they call a *mia mia* They cut down branches and lean them up against the trunk of the trees Under this they sleep, huddled together like animals In the entrance, they usually have a sma

of course

vented by

further the situation of these people with more modern equipment

I should also point out that many of the earlier travelers among primitive tribes such as the Chukchis in Siberia describe superior endurance to cold exposure in these tribes (5) Many of these descriptions may be *misleading since often the observer himself was seated inactively* on a sled, very well clothed but thoroughly chilled in the course of a day This chilled observer would observe the natives running around lightly clad and working with bare hands in the cold failing to realize that

Eskimo lives under tropical or subtropical

quoted the Eskimo is generally speaking considered to be subject to considerable cold exposure *It would therefore be reasonable to assume* that, if any modification or any change would occur, you would expect *to find* some change in these people *who have survived successfully* along the shores of the Arctic Ocean for thousands of years

Since none of the other primitive tribes is available to us here in this area for study we have focused our attention on the Alaskan Eskimo This will then be the subject for my discussion from now on

*Dalton R Personal communication Melbourne Australia 1957

I should like, for the purpose of this discussion, to compare our findings in the Eskimo with the rat exposed to 5°C, and with white controls, where possible

In most rat experiments, the animals have been exposed to environmental temperatures of around 5°C, and if kept there for 4 to 6 weeks, it is generally agreed that the following changes occur (7,8) There is a marked increase in metabolism, up to several times that of the basal level, and about 60 to 100 per cent increase in food intake There is an increase in cellular metabolism and increased vascularization of muscle [illegible]

But the most outstanding feature appears to be that the acclimatized rat has the ability to maintain a high level of metabolism, and that the unacclimatized rat does not have this ability and, consequently, is unable to survive

Travell What were the changes in the ascorbic acid requirement?

Rodahl Increased requirements There is an initial reduction in ascorbic acid content of organs in cold exposed rats the ascorbic acid excretion in the urine is increased Additional ascorbic acid in the diet increases resistance to cold in animals (8) Isn t that it?

Travell That is what I was asking

Rodahl We will come back to the ascorbic acid requirement in the Eskimo later, if you wish

Fremont Smith Rats make their own ascorbic acid

Rodahl Indeed Let us consider the environmental exposure first It is quite obvious that a rat exposed to 5°C is probably far more severely exposed than any of the primitive tribes mentioned so far For, according to available figures, a comparable exposure in man would in reality mean the exposure of nude subjects to temperatures roughly, 5° to 10°C or slightly higher, continuously for several weeks

In the Australian aborigines, exposure to temperatures of this level takes place only for short periods of time and rather irregularly These people can go to sleep, knowing that the sun will rise and warm them up in the morning It approaches the situation of some of Dr Hock s hibernating animals The Eskimo s clothing has a clo value of 7 to 14 clos, which is certainly adequate for maintaining thermal balance under all conditions encountered The fact must also be taken into account that the Es[illegible] that he has no business

sleeping and less than 4 clos while active at $-40°C$ This can b achieved by one to two layers of caribou fur (8,10)

Fremont Smith Will you tell us what a clo unit is?

Rodahl I will ask Dr Burton to define the clo unit

Burton It is defined in terms of the amount of clothing insulatio required to keep a man indefinitely at about 70°F with a resting metabolism This corresponds very much with what people wear, *e g*, a business suit A light overcoat adds an additional clo unit An Arctic uniform is perhaps 6 or 7 clo units

Rodahl In the case of the arctic uniform or flying clothing, the total clo value is slightly less than 4 clos, in fact, it may be 3 5 clos, the way most people dress This, according to Dr Burton (8), would be adequate to protect a man down to $-40°F$, for practical purposes Environmental conditions lower than this in the central part of Alaska, where we have little wind, with temperatures lower than $-40°F$ occur less than 2 days in the month of January Here we are able to equip a man with what he needs, and if the temperature should go down to lower than $-40°F$, he would have to exercise Here is where physical fitness comes in This, of course, is the principle for our walk around sleeping bag If the temperature is lower than the figures we mentioned, the survivor will have to get up and exercise By surrounding himself with a sleeping bag where he can put his feet out through a hole in the bottom, he can preserve his layers of warm air next to his body for a longer period of time

The significance of heat loss by radiation in clear arctic nights has been pointed out by Hardy and Stoll (11) on the basis of work done here in arctic Alaska They find by taking into consideration the heat loss by long wave radiation to the night sky, that the exposure may be considerably more severe than the ambient temperature would indicate

Also, exposure of the face to convective heat radiation loss amounts to probably less than 10 per cent of the total metabolism in most instances, if it is assumed that the area is about 300 cm^2 The long wave radiation under these conditions would be, roughly, 0 408 cal /cm^2/min at a maximum

The Eskimo s face is surely exposed to rather extreme cold for prolonged periods of time This is something that escaped our attention We talk about the fingers and the hands, but they are usually protected, the face is not

The added heat loss through the exchange of respiratory air in man exposed to cold is not of great importance Webb (12) has shown in Alaska that the difference in respiratory heat loss between a man standing at 0° and $-40°F$ is of the order of 3 calories

Since it is quite essential to know exactly the magnitude and the duration of the environmental exposure the effect of which we are measuring physiologically we have collected data from time to time over the last 6 or 7 years pertaining to the environmental exposure of the Alaskan Eskimo

[illegible]

roughly 70°F The night temperature again varies considerably depending on the construction of the house and how much fuel the inhabitants have As a rule the stoves are let to die out at night The mean here is 50°F So there is a difference of 20 degrees between day and night temperatures In most whites houses in Alaska the temperature is the same day and night

We should emphasize that in periods of bad weather the Eskimo does not spend much time outside unless he is caught in bad weather We found as a rule his daily outdoor activity often amounts to less than one hour He will only get out to collect wood ice and so forth

Horvath Tell us which is the coldest environment out of curiosity

Rodahl As a rule we can put it this way on the coast there is a combination of wind and temperature The temperatures very rarely go down to −40°F but the average wind speed on the Arctic Coast for instance at Wainwright Point Hope and Barter Island is over 4 miles an hour 90 per cent of the time So there is the combination of wind chill and cold

In the interior the same thing applies to the Anaktuvuk Pass in the Brooks Range Gambell St Lawrence Island again is windy and cold but temperatures seldom go below −40°F

Kark Do Eskimos ever change their dwellings?

Rodahl Yes very often As a matter of fact we notice the change from year to year When I arrived at Anaktuvuk Pass in 1951 they were living in skin tents Now they are all living in sod houses The Gambell Eskimos all live in wooden houses This change was introduced in 1910 At Point Hope and Wainwright they are still living in houses of driftwood and sod In any case the houses offer good protection from heat loss

In fair weather the daily amount of activity outside in the summer amounts to 5 to 9 hours on an average for our Eskimos We arrived at this on the basis of time activity data when we were following the activ

TABLE X

Temperatures in Different Eskimo Houses During Various Seasons of the Year

Location	Type of Dwelling	Temperature (of)	
		Night	Day
Anaktuvuk Pass			
Summer	Tent	63 (50 to 72)	75 (65 to 85)
Winter	Sod	35 (30 to 40)	68 (60 to 90)
Barter Island			
Summer	Sod covered, wood	40 (20 to 55)	59 (38 to 75)
Winter	Sod covered, wood	40 (10 to 50)	60 (35 to 75)
Wainwright			
Summer	Wood	48 (—)	69 (58 to 79)
Point Hope			
Summer	Sod covered, wood	63 (48 to 73)	68 (57 to 79)
Winter		29 (10 to 63)	62 (37 to 76)
Kotzebue			
Summer	Wood	65 (60 to 70)	72 (68 to 92)
	Tent	55 (48 to 65)	80 (50 to 104)
Winter	Wood	65 (50 to 70)	80 (55 to 95)
	Tent	45 (20 to 60)	70 (50 to 98)
Napaiskak			
Winter	Sod covered, wood	42 (0 to 75)	72 (60 to 85)
Gambell			
Summer	Wood	60 (45 to 75)	70 (60 to 105)
Winter	Wood	55 (20 to 65)	70 (50 to 90)

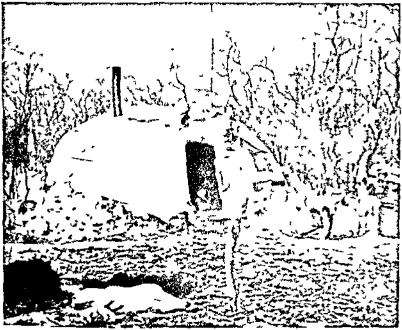


FIGURE 51 Skin tent at Anaktuvuk Pass

Pass, constructed over a frame of willow and covered with about 21 undyed caribou skins The door is usually of bearskin or caribou This can be taken down and moved from place to place The sequence of events in the recent development is that when the Eskimos got a post office they started to become more stationary, and then they switched to more permanent dwellings (Figure 53)

Figure 54 shows typical Gambell houses This is on St Lawrence Island

In the early days the Eskimos lived in a dome shaped tent made of several layers of walrus skin Then in the spring they moved out of this, opened it, aired it, and cleaned it while living in the summer tent next door They then moved back into the skin tent for the winter Now we have given them wooden houses where they accumulate the dirt and filth from year to year They only use one room anyway The rest is for washing machines they can t use

At Thule, Northwest Greenland, the Eskimos live in houses of wood and sod One of the houses was nothing but a glider plane During a storm the glider had been blown away from the air base The Eskimos

FIGURE 52 Interior

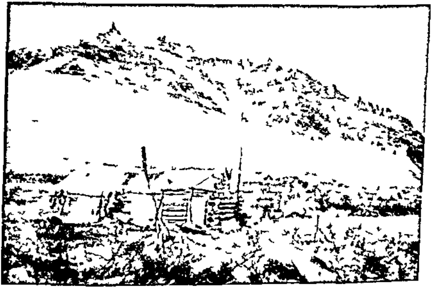
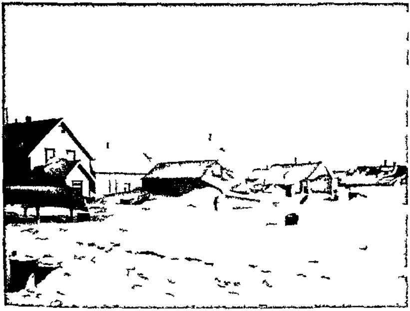


FIGURE 53 Log house at Anaktuvuk Pass



F GURE 54 Esk mo house at Gambell

FIGURE 55 Dog d er

ho had found t on the ce had hauled t n to the v llage They have a great ab l ty to adapt themselves to environment and use mater als that are ava lable

FIGURE 52 Interior

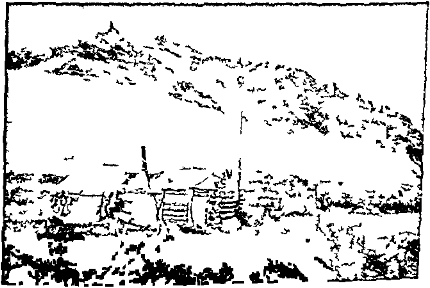


FIGURE 53 Log house at Anaktuvuk Pass

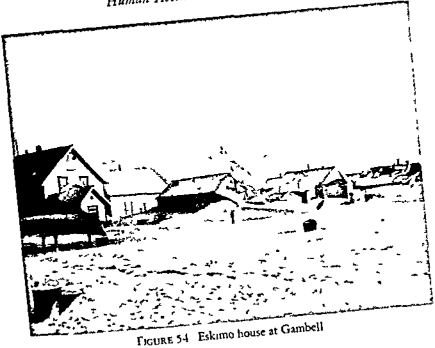


Figure 54 Eskimo house at Gambell

Figure 55 Dog driver

who had found it on the ice had hauled it in to the village Th
have a great ability to adapt themselves to environment and use mater

We pointed out that the Eskimos have great stamina and that when exposed they are rather active Figure 55 shows a typical dog driver and the way he runs behind the sled for hour after hour He runs at a moderate pace so that he does not exhaust himself He maintains thermal balance and that is all But his face is exposed (Figure 56)

The same thing is true for the women (Figures 57 58) When fishing they have two sticks by which they can lower the line or bring it up *without touching the line with the hands They wear mittens but* the face is always exposed

Carlson Could you tell us what the temperature might be where the woman is? She is wearing only ordinary gloves

Rodahl This is characteristic The Eskimos when out working use cotton gloves They are quite adequate as long as you are active

FIGURE 56. Eskimo face

FIGURE 57 Eskimo girls at Anaktuvuk Pass

Carlson She is just sitting there

Rodahl Yes, but she is dressed in caribou fur All she has to do is to pull her hands inside her sleeves, and they do this often She does not stay there very long, an hour or two, and then goes back to the house When they sit for a long time on the sled, I have seen the Thule Eskimos use polar bear mittens in which they put the whole hand, and they also have extra mukluks which they put on on top of those they normally wear, so they can sit there almost indefinitely, very well protected

Figure 59 shows the old Jajok at Kotzebue, who is 83 years old Again, he is wearing fur clothing and he uses the cotton mittens, but his face is exposed

Blair Isn t that a fantastic age for the Eskimo?

Rodahl Not really I would say the Eskimos who survive infantile mortality and childhood tuberculosis, etc often live to get that old Of course, accidents take a lot of lives, too When they get that old, they don t do much So, the chance of dying in an accident is not very great

Figure 60 shows the famous old Ootah who marched with Robert

FIGURE 58 Eskimo woman fishing

Peary to the North Pole in 1909 He died about a year ago, but when I took this picture in Thule Northwest Greenland, he was very much alive indeed He was eighty some years old He is covered in fur but *his face is exposed completely*

In summary, we may say that it is hardly justifiable to compare the Eskimo in his normal environment with the rat exposed to a temperature of 5°C When speaking about general acclimatization to cold *If we want to compare the two we will either have to expose the rat to more* moderate temperatures or the Eskimo to more severe temperatures

Whereas the rat exposed to a temperature of 5°C has to more than double its *metabolic* rate *to survive*, we have no evidence that the metabolic rate of the Eskimo exposed to the outdoors is materially increased

Carlson I once checked Dr Horvath s rat data with 4 or 5 clos at −40°F and the skin temperatures approximate those of a man at 10°F So, I wonder if the temperatures you have on these people *sitting*

FIGURE 59 Jajok at Kotzebue

on the ice really justify your saying they are completely protected by the caribou skins Four clo units would require considerable activity at −40°F to keep the person warm Do you know anything about the temperature distribution in the Eskimo while he is out on the ice fishing for example?

Rodahl When actually exposed to such temperatures the Eskimos would have at least two layers of caribou We feel from data by Burton (8) and others (10) that this would amount to at least 12 clos

Fremont Smith You actually have skin temperature measurements of such Eskimos?

Rodahl Not sitting but Dr Rennie* did some work on an Eskimo walking on a hard packed snow surface His energy expenditure was 145 cal /m²/hour

Horvath At −10 F a man can shed down to his underwear and

*Rennie D W Personal communication 1955

Figure 60 Ootah at Thule

still be very comfortable at that metabolic level I don t see the com parison This Eskimo is wearing most of his clothing, although he probably ventilated It is even possible to walk about practically in the nude at $-40°F$ and get along perfectly well

Rodahl The Eskimo sets a pace which is just enough to keep him warm Furthermore, his clothing offers excellent insulation, so that he can retain whatever warmth he has, if needed Actually, if you take the figures published for the clo value of caribou fur (10), assuming the Eskimo has up to three inches of it on him, this would amount to about 12 clos

Burton I am astonished that it can be that high, but I can well believe it We find, with our design of military clothing, when we get up to 6 or 7 clos, the man s mobility is so much affected we can t go higher I have no doubt that the Eskimo, with his experience, has solved the problem of clothing design, so that he could possibly get 12 clos and still be mobile

Rodahl This is the point If you accept the clo value for caribou fur on the basis of the data of Scholander, Walters, Hock, and Irving (10), and if you double that by two layers of caribou fur, which the Eskimos certainly have when exposed, you get 12 clos Normally, the Eskimos will have one pair of inner pants of caribou and one pair of outer pants of caribou The fur side of the inner pants faces in and the fur side of the outer pants faces out When Eskimos sit on the sled, they sometimes have in addition to their skin socks and fur mukluks, extra mukluks to put on

Horvath In the early days of the war, before we began to be militarized in our type of clothing, we did try to simulate the Eskimo type of clothing We wore the relatively thick pile, about one inch, and two layers, with one pile layer inside and one outside It was rather unwieldy and bulky, no one liked it, but it was certainly an efficient type of clothing

Burton A very good rule of reckoning is that the best type of clothing has 4 clos per inch I can well believe that the Eskimo woman shown fishing, in Figure 58, had as much as 3 inches of fur insulation between her and the skin That would be 12 clos

Rodahl Yes

Burton The military don t seem to find they can wear that amount and perform military duties

Rodahl The problem is that there isn t enough caribou fur to go around Also, there is the problem of cleaning and there is the problem of molting Fur flying around in an airplane might get in the engine In Greenland I got caribou hair inside my watch!

Our hope is to develop artificial material which will be equal to caribou fur in insulation value and practicability In addition, we should learn from the Eskimo his principles for clothing design In the first place, he has these few layers When he gets into the house he can take off one layer and he is comfortable If he has to go out in a hurry, he only has to put on one layer, and he is ready Whereas our soldier, [illegible] a great heap of clothing on the floor

[illegible] e total

[illegible] weigh

[illegible] much

himself It is a tremendous load Anything that can be done to improve this situation would certainly be beneficial

Irving Dr Rodahl implied the nicety of fit in the Eskimo clothing which comes both from the original construction, tailoring and design and, also, from the constant improvisation and adjustment that the person himself applies to it

One difference in the way the Eskimo and the military man wear these clothes can be illustrated by an experience I had as we were walking over to mess I spoke to Dr Whaley but he didn t hear me because he had his parka up over his face When he turned around to speak to me, his head turned but his parka didn t We were not in a very good state of communication there for a while The Eskimo has his parka so fitted that, when he turns his head, he can still see With just a few, to me yet incomprehensible flips he can throw the whole thing back from his face and have his entire head cleared He can stick out his arms, or can pull them back in

The fabric, the fur substance itself, too, in contrast with our rather stiff equipment, drapes close to the body So when he sits he is really, genuinely sealed at all points He can reduce his bulk considerably while practically increasing the effectiveness of the thickness of his insulation

All those are tricks, which I am very glad to hear Dr Rodahl is emphasizing, we must search out in the Eskimo clothing at least for an understanding of how to get around in the Arctic

Horvath That isn t the problem That was already searched for back about 1942, Dr Irving That kind of equipment is not considered practical for military use We started out with that concept way back at that time We were working on that kind of clothing, made of pile and gradually developed this more complex and rather unwieldy thing However, we started off with the correct basic idea We know the importance of this but we just do not have any way of implementing for the service of the military

Blair Of course, the big difference in the whole concept of clothing as applied to the Eskimo and to the military man in the Arctic is that the soldier must adjust his clothing for different types of tasks in different environments, whereas the Eskimo puts on a set of clothing and

clothes The Eskimo

ough

is not sufficiently well known Returning to Colonel Blair s remarks, I may add that the Eskimo has a fitted uniform, not just an issue The military man gets something that is given to him, and that is it On the other hand, the Eskimo s clothing is tailor made His hood fits exactly around his face, but his face is exposed He will also wear this same clothing winter and summer Furthermore, he has the perfect fit Dr Irving described In addition, Eskimos can withdraw their arms, if they want to do something else In this one limited garment they have the ability to adjust for heat loss

Also, the Eskimo clothing has one advantage which is often overlooked by the physiologist, it keeps the skin clean The caribou rubs the skin continuously, and removes the dirty surface epidermis as it peals off

Horvath We appreciate that but it is important to keep in mind the fact that the people of our nation have been brought up on the concept that a layer of underwear against their skin is necessary, otherwise they are never clean

Burton For Dr Horvath s protection, as well as mine, I should like to say that the decision that the features of Eskimo clothing were not adaptable for military use was not that of the scientist but of the military people

Rodahl My remark applied in general Many fundamental principles may have been uncovered without having been generally recognized In addition to that, Dr Burton s remark is of extreme importance It is the scientist s job also to educate the military in some cases

Talbott One of the things we did appreciate was the Eskimo clothing The arctic clothing we started out to use in 1940 and 1941 and abandoned by 1943 was only partially successful in providing protection and mobility We had protection with the arctic clothing and we had mobility if we didn t take full advantage of it but we just couldn t get the combination of full protection and full mobility or really carry on a combat operation and perform all the necessary operations that the military wanted us to with that type of clothing

Fremont Smith Can the Eskimo do all that the military want? Do they have military mobility or only Eskimo mobility, which might be different?

Talbott All they have is Eskimo mobility

Burton Dr Talbott s remark is to the point It is a question of not only having the equipment, having the style of clothing, but knowing how to use it This is something that the Eskimo knows, and, apparently, it is very difficult to teach to hundreds of thousands of G I s

Talbott Impossible, probably

Blair The instruments and tools used by the Eskimo have been developed over centuries for use with his mittens and type of clothing whereas military equipment being used is not adaptable to that particular type of clothing We either must adapt the man to use his equipment in the Arctic or we must adapt all equipment to Eskimo type clothing It is much simpler to adapt the man

Fremont Smith Let us put it this sharply The Eskimo clothing which is wonderful for him really would not make it possible for him to perform the military needs in terms of mobility If this is true it changes the situation If it isn t true we ought to be able to use Eskimo clothing

Horvath Your statement would be all right if you substitute the word maybe for really

Kark The problem is not that it is impossible to teach G I s to use Eskimo clothing but that there is no time or opportunity It takes a long time for them to learn This must be done over a long period of time and the whole army must be taught

Fremont Smith Does the Eskimo have military mobility? It seems to me this is the first question we have to settle If we know this we have a base from which to move

At the present time we have been discussing this on two levels first that the Eskimo is perfectly equipped to do anything he wants to and therefore we should be able to use his clothing and second that the Eskimo can t Which is it?

Rodahl May I say this to help straighten out some misconception First isn t it fair to consider the clothing as part of the weapons system? Man has to have the clothing as a part of himself Second we all agree it isn t practical for the soldier to use the Eskimo fur clothing That is I think settled But the principles and some of the things we can learn from studying the clothing would be applicable

What we hope to find in the future is artificial material which is equal to the fur in insulation value and practicability so that there are two layers of clothing which would give these clos and so that we can take off one layer when warm and put on the other one when cold I think that would solve the problem

I may add that the Eskimo would probably be useful in certain kinds of arctic patrols because of his superior ability to operate in the cold In arctic warfare the outcome depends on the individual soldier He who can operate at one degree colder than the enemy can sneak in and catch him helplessly trapped in the sleeping bag

Horvath Let me go back into a bivalent personality Actually it becomes somewhat difficult to operate a tank or a plane in the kind of

and let him try to drive it around, the fur gets into everything

Rodahl This problem brought up by Dr Burton is essential It is a question of cultivation Just as you have to cultivate a rose, cultivate the ground and allow the plant to adjust itself to the environment, so you have to cultivate those who are to operate in the Arctic It is a combination of equipment and know how, diet, skill, etc It is not sufficient simply to give a soldier the best equipment, because it is going to be useless unless he has the capability of applying it fully It is a complex situation where the whole man s knowledge, his skill his ability, his physical fitness, etc , must be considered

I suggest the introduction of the word cultivation rather than "acclimatization because according to the dictionary cultivation means to cultivate, to improve or develop by study, exercise, or training

Currie I have discussed at length with Stefánsson this question of arctic clothing I have a recent letter in which he summarized his problems in trying since 1919 to get the American forces to adapt the Eskimo design and specifically he made recommendations in 1940 He gave me three pages of the difficulties he ran into while trying to put these ideas across I should like to give you his conclusion He said that even these were not his most serious handicaps His worst hurdle was mental The human mind is baffled by simplicity

Meehan The Quartermaster Corps has an advisory board on environmental protection. I am on a subcommittee of this board, concerned with hand protection and hand wear in cold Recently, a symposium was held on the subject at Natick. The one conclusion from the symposium which I think is important to point out is this that the clothing is only part of the military man s total equipment and has to be integrated with all of the equipment that he has to handle or deal with during his normal activities For example, such things as the type of material that is used in a gunstock and in the trigger may affect appreciably the amount of heat loss that he will experience from his hand, when he is actually manipulating this equipment in the cold

that face the soldier Much can be done in the design of military equipment as far as hand wear is concerned, by using materials, for

Blair The instruments and tools used by the Eskimo have been developed over centuries for use with his mittens and type of clothing whereas military equipment being used is not adaptable to that particular type of clothing We either must adapt the man to use his equipment in the Arctic or we must adapt all equipment to Eskimo type clothing It is much simpler to adapt the man

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Horvath Your statement would be all right if you substitute the word maybe for really

Kark The problem is not that it is impossible to teach G I s to use Eskimo clothing but that there is no time or opportunity It takes a long time for them to learn This must be done over a long period of time and the whole army must be taught

Fremont Smith Does the Eskimo have military mobility? It seems to me this is the first question we have to settle If we know this we have a base from which to move

At the present time we have been discussing this on two levels first that the Eskimo is perfectly equipped to do anything he wants to and therefore we should be able to use his clothing and second that the Eskimo can t Which is it?

Rodahl May I say this to help straighten out some misconception First isn t it fair to consider the clothing as part of the weapons sys

Second we

clothing

things we

can learn from studying the clothing would be applicable

What we hope to find in the future is artificial material which is equal to the fur in insulation value and practicability so that there are two layers of clothing which would give these clos and so that we can take off one layer when warm and put on the other one when cold I think that would solve the problem

I may add that the Eskimo would probably be useful in certain kinds of arctic patrols because of his superior ability to operate in the cold In arctic warfare the outcome depends on the individual soldier He who can operate at one degree colder than the enemy can sneak in and catch him helplessly trapped in the sleeping bag

Horvath Let me go back into a bivalent personality Actually it becomes somewhat difficult to operate a tank or a plane in the kind of

clothing that the Eskimo has There is a step in between which is certainly what we are really trying to get that intermediate stage where we apply some of the basic principles of Eskimo clothing and keep in mind the limitations of working in certain kinds of enclosed spaces which have in themselves limiting factors If you put an Eskimo into a tank and let him try to drive it around the fur gets into everything

Rodahl This problem brought up by Dr Burton is essential It is a question of cultivation Just as you have to cultivate a rose cultivate the ground and allow the plant to adjust itself to the environment so you have to cultivate those who are to operate in the Arctic It is a combination of equipment and know how diet skill etc It is not sufficient simply to give a soldier the best equipment because it is going to be useless unless he has the capability of applying it fully It is a complex situation where the whole man s knowledge his skill his ability his physical fitness etc must be considered

I suggest the introduction of the word cultivation rather than acclimatization because according to the dictionary cultivation means to cultivate to improve or develop by study exercise or training

Currie I have discussed at length with Stefansson this question of arctic clothing I have a recent letter in which he summarized his problems in trying since 1919 to get the American forces to adapt the Eskimo design and specifically he made recommendations in 1910 He gave me three pages of the difficulties he ran into while trying to put these ideas across I should like to give you his conclusion He said that even these were not his most serious handicaps His worst hurdle was mental The human mind is baffled by simplicity

Meehan The Quartermaster Corps has an advisory board on environmental protection I am on a subcommittee of this board concerned with hand protection and hand wear in cold Recently a symposium was held on the subject at Natick The one conclusion from the symposium which I think is important to point out is this that the clothing is only part of the military man s total equipment and has to be integrated with all of the equipment that he has to handle or deal with during his normal activities For example such things as the type of material that is used in a gunstock and in the trigger may affect appreciably the amount of heat loss that he will experience from his hand when he is actually manipulating this equipment in the cold

Not only is there a chance to improve hand wear *per se* but also we should look at the design of the equipment that the military man has to handle and use and give some attention to the physiologic problems that face the soldier Much can be done in the design of military equipment as far as hand wear is concerned by using materials for

example, that have low heat capacity and low heat conductivity, such that the man is not going to incur great cooling in his hand by having an article that will conduct a fair amount of heat away from his hands

The prospects of improving greatly, from the technical standpoint the materials that we have for insulation, especially as applied to the hands, are not too great in the near future The practical solution is going to come probably from compromise between the application of materials that we either have or can foresee, and, at the same time, interest the engineers that design the equipment that the military man would use, in giving consideration to the operational requirement of these things a little more carefully

Horvath One of the things that impressed me most at Fort Churchill (Third Conference ... the Eskimo of the loadi ... between the way he ... G I did it was stupendous I think one of the comments Dr Rodahl made about accustomization is really a great part of this

Fremont Smith Did he load it very well or badly?

Horvath Very well

Rodahl This discussion brought out the need of another conference on clothing

Irving Dr Rodahl stands as an individual defending the merits of the Eskimo clothing and the methods for its use Perhaps if he will constitute a committee of one, he could better present and further carry out the study of the genuine merits and qualities of Eskimo clothing and the ways in which it is used

Rodahl We have available here the material, the people, and finally also the instrumentation that is needed for such studies

Irving You might very well have turned the argument in a quite different direction had you asked, in reply to these questions illustrating the inferior quality of Eskimo equipment and certain military necessities, Is our soldier able to operate under arctic conditions? Is he able to move or exist with anywhere near the capability that the Eskimo even at present possesses?

Rodahl No doubt about it

Irving That is, for all the merits of clothing which you people are rightly ... and still unable to move ir...

Roda... ponent probably is worse off than we are and, on top of that, we aren't so badly off at this moment, depending on what you want our soldiers to do

We pointed out that our arctic uniform or flying clothing will take

care of an active man down to $-40°F$ (13) Temperatures lower than that in certain areas such as this are not frequent, occurring something like 4 per cent of the time If you want to use the arctic as a friend and ally rather than an enemy, then we must go further This has been done many times

Talbott I would like to ask one question before you go on How long do you think it would take the average G I to be properly indoctrinated, the G I who comes from Wisconsin, not a farm but from the city, or comes from Tennessee or Florida, who is one of 200,000 troops that has to be properly taught to use his clothing and not only to survive but to be one second faster than the enemy? How long is it going to take, per man, to get this vast bulk of combat troops properly indoctrinated?

Rodahl I would like to answer that question by saying there are two sides to the story One is the individual variability, and, the other is the method by which this is accomplished As it is now, often a body of soldiers is composed of Negroes, Polynesians, whites, etc They come here in winter, perhaps in inferior physical condition Some have possibly never seen snow before and most of them really do not know how to ski They put 125 pounds of equipment on such a man, give him skis, and say, Here you are, ski It is $-30°F$ He has the combination of lack of fitness, lack of know how at skiing, and environmental exposure all at once

If this were done in gradual steps, starting with physical fitness and tough training until he is hard as a nail and then if he is sent to a ski school in the States, where the environment is pleasant and not too cold, so that he can learn to enjoy skiing, when he is fit and can ski he can be brought to Alaska The cold and equipment can be added and he will do well in a short period of time

Talbott You have evaded the issue

Rodahl This comes as the second part of the question the individual variability In some cases, this result will never be achieved I remember a moving picture Sir Hubert Wilkins once took of infantry troops at the end of 2 years of training They were coming back from a 6 weeks maneuver and were operating on skis, it was quite pathetic They carried their equipment on their backs, and they needed a team of three to keep at least one upright all the time One would stumble and his pack would fall forward over his head, and he would dive into the snow, all you could see were the skis The next man would come along, pull him up, and go down The third man would eventually get one up They would change to snowshoes and the result would be the same A certain amount of experience is required for that, also

Here we had troops that had been trained for 2 years and yet had not achieved the basic principles In contrast to this we have seen men who have achieved quite adequate standards as ski troops in the course of one winter

I would say that if you were really seriously focusing your attention on what we used to think of as an arctic winter warfare unit, you could probably achieve all this in one year

During the last war, I was ski instructor and winter warfare instructor for the 52nd Highland Division which was composed of little Scotsmen with great courage They did very well

Currie I would go one point further, in one category We have some air crews equipped with experimental clothing that has been de signed and fabricated here It looks very crude, however, we have tried to incorporate in this clothing some of the principles that we have known about, and to adopt these principles of insulation and design from the Eskimo garment These pilots can wear this garment, and no training is required to use it In suiting up for scramble, we can get them out in about the same time, or about one minute earlier Also, they are more comfortable while in the alert room because of the design of this clothing which keeps them from being wet with perspiration when they get in the cockpit of their aircraft, this is a very important factor

Fremont Smith Why isn t the alert room here at Ladd kept cool?

Currie There are people there who have to work with their hands and others who are suited up

Fremont Smith It was so hot that anyone would be uncomfortable in his ordinary clothing

Currie In the alert room downstairs where the crew chiefs are, there are people who have to work outside and that room is cold The pilots go right from that alert room and get into the warm cockpit

Talbott Do you have an estimate of the clo value of the experimental clothing?

Currie We have not been able to estimate it, but the pilots prefer it to their normal clothing

Talbott Do you think it is much more than 4 clos?

Currie That is one thing we have to check

Kark May I talk to Dr Rodahl s point? I think his point is very well taken He is an expert on living in the arctic and training a group of untrained soldiers to be comfortable in the cold I saw some of his troops when they were in Canada They were expert skiers and lived in the glacier

How many men are there like Dr Rodahl to train our soldiers if

there is a sudden emergency? If for example the Army suddenly expands to two million how many men will there be to train these troops? The problem in wartime is that you are suddenly burdened with a large number of men who have to be taught basic infantry maneuvers and when you try to add to that the problems of learning to live in the arctic it becomes extremely difficult

Horvath In the old Inca civilization where there was a high altitude and a low altitude two separate and distinct armies were maintained

Blair We have overlooked one very important point The very fine reports of Dr McCollum (14) from this laboratory show that motivation and psychologic adaptation are very important One of the first things to be considered is proper psychologic adjustment of the man to the Arctic Many boys particularly from Florida and other southern states come here with a marked innate fear of the cold Until you alleviate this inborn fear you cannot teach them to use clothing skis or any other Arctic equipment efficiently

Rodahl This is part of the whole cultivation complex Dr Kark the correct approach is obviously to establish an arctic Army skeleton composed of perfectly trained capable people who can immediately [illegible]

are willing to volunteer to such a unit I am afraid that the general philosophy is now that all men are alike and that they all should be able to do these things equally well at short notice Obviously this is not so

Fremont Smith In the Air Force the pilots are specialists You don t say that everyone has to be a pilot Therefore there is no reason why the same principle can t apply and say that not everyone has to be an arctic man but there are special arctic corps troops There should also be tropical desert troops We already have this It is really an extension of the concept of specialization which has already been accepted with limitations within the military It isn t a new kind of concept that we are trying to introduce It should be possible to support this point of view that Dr Rodahl has made and somehow we should be able to give some vigor to that

Meehan The requirements between the Army and the Air Force are somewhat different as the Air Force has a much greater mobility Their pilots can be as you know in a warm environment at one moment and very shortly in a cold environment

In the course of my normal activities I have had the opportunity to consult with the local aircraft industry in Los Angeles on some matters

One of the major problems that is very practical to the aircraft designer is getting good, concrete information on the problems that we have discussed here, so that basic ideas can be incorporated in such areas as cockpit design There is a lot of talk about this, but unless this information actually filters back down into the hands of the people that are doing the most original design work, the solutions to these problems come only as a secondary matter, and they are never entirely satisfactory This is a real problem, and it is something that the Air Force should consider from a very practical standpoint I am sure it also applies even to the Army situation in the design of their own equipment

Horvath This all goes back to what Dr Fremont Smith said earlier It is a matter of communication A lot of information is available There are in this group at least a dozen men who were concerned with doing this sort of thing during the war, who made a tremendous number of contributions in that area, which I think could be well utilized even at the present time These contributions may be slightly out of date, but I think the basic information is there Somehow or other we don t seem to be able to get this information back to the right people

Behnke The problem is complex Let us forget the ground troops The environment of the aviator is very rapidly changing compared with that of the Eskimo Also, in addition to the usual clothing, the aviator has the oxygen breathing apparatus, the immersion suit, and other protective equipment There has been too much emphasis on the possibility of getting some kind of a single garment that can be put on and that would take care of all the rapidly changing environmental conditions within a short time The concept should be that there are different types of equipment which, like the control panel board of the aircraft the aviator himself must adjust, put on, or take off, and these types of equipment should enable him to combat his personal environment It is not simply a matter of a single suit of underwear to do the job

Meehan This is a difficult problem in the cockpit of the F 104

Currie This is a group that can contribute a great deal to the solution of Captain Behnke s and Colonel Blair s and our problem in the future But we are thinking here in terms of a stabilized warfare such as we had in World War II When we think of design of clothing, and when we think of the pilot, let us think of the military personnel, Army, Navy, and Air Force, who might be back in South Carolina or Florida or Minnesota who are highly mobile It may be the Army, it may be the Navy, it may be the Air Force But our concept, as General Eisenhower has it planned, is a small defense organization capable of a rapid strike and rapid deployment of people back in the Zone of the Interior So Colonel Blair s men will get into an aircraft and go into a

ge environment just as rapidly as our pilots do, because they will be airplane with our pilots We have to think in terms of the ground s and the support troops One of the most important issues that ome up in this discussion is what Captain Behnke just said, *i e*, an t design an all purpose uniform for the military

aps have only one bomb With that bomb on the target, he has his job The operational capability is of foremost importance, the val comes second

the case of arctic operations, we will have to consider the austere itions under which some of the ground crews will have to operate aft In the case of a major catastrophe in an all out campaign, you have to ask more of the people who keep these airplanes flying in s of endurance to cold, physical fitness, stamina, etc While clothing irement will change a high level of physical fitness is always going e a basic need, and this is something all can do a great deal about —to make these people physically fit to perform

ark I did want to talk about the terrible debacle in Attu in World II, when hard trained desert troops were taken directly from the fornia desert into the Aleutian Islands to prevent the Japanese sion of America Their casualties from frostbite and cold injury just fantastic

remont Smith The casualties from neuroses were also fantastic ink these were probably more fantastic than the ones from the tbite

Horvath That was due partly to the failure of communication to the right kind of equipment to these men

ark I am just pointing it out

Horvath It certainly was a sad experience

ehnke I think Dr Rodahl has some answers

Rodahl Isn t it true to say that in the technical aspect of arctic opera s we really do not know many of the basic problems involved? First ll, we do not know the environmental exposure to which the soldier l be exposed, or expected to be exposed For instance, how often uld you expect a man on the Arctic coast to run into a combination of peratures and wind conditions of such and such a nature? We do know this for all of Alaska, not to speak of some of the interior t of the Polar Basin When we landed on T 3 in 1952, for instance, cold was far more severe than anything we expected According to

the charts available, we expected it to be fairly moderate We were almost freezing to death

We need data as to the environmental exposure, the degree and duration of the exposure Finally, we need to know specifically what a man is supposed to do This, of course, will then determine the clothing requirement, dietary requirement, etc So far, it seems to me no one is able to give us all these answers Isn't that correct?

Talbott You mean the temperature charts* of Paul Siple are not adequate for this area?

Rodahl This is not simply a question of temperature and wind chill We want to know how many hours or minutes of the day the temperature is likely to fall to −30°, −40° or −50°F, without wind or with wind, in certain areas because this would then be the basis for setting up the requirements for clothing and protection For instance, for the central North Polar Basin we do not have the figures We have a few spots only

Burton I should like to support Dr Rodahl I have tried to emphasize (8) that the meteorologic data, even where we have them, are not in the form we want They are not frequency data Moreover, we do not want just frequency data of how often the temperature is at such a level, but we want combined double frequency data with the wind as well

During the war we had the absurdity of committees laying down requirements for building, say, Arctic shelters, in which they said we must provide for temperatures of 70°F below, with a 60 mile an hour wind How often does one experience a combination of 70°F below and 60 mile an hour wind? Probably never

Progress can be made however, because the British Navy, realizing this point have prepared charts for the whole of the North Atlantic, with double frequency data It can be done, and it should be activated for areas such as this

Rodahl What about radiation?

Burton Radiation can be taken into account We have the basic ways in which we can put these together to get the right answer for the stress on the man, but we haven t the material to do it

Rodahl I was really more or less emphasizing what you said in your book The second thing we have agreed upon is that the Eskimo is really fairly well protected to meet the range from inactivity to activity, from warm to cold temperatures

*Unpublished

Hildes Are you going to say something about the evidence in favor of your statement that physical fitness is an important thing?

Rodahl I will discuss that a little later The question is often asked Is there any change in the preferred or comfort temperature of a person during the arctic winter? Years ago five subjects slept in the nude here in a temperature-controlled room under Dr Bolerud s direction They were allowed to adjust the temperature themselves to comfort level Skin temperatures were taken and also metabolic rates We found there was no difference in the preferred temperature throughout the period from December through June

Blair Is that true for Eskimos as well as soldiers?

Rodahl We have not done this on Eskimos We also found there was no difference in metabolic rate but there was a slight seasonal difference in skin temperatures taken in the morning and in the evening however the difference was not statistically significant There was a tend ncy for lower skin temperatures in the winter as compared with the summer Whether this is just a seasonal fluctuation we do not know or the other

In the case of the Eskimo we may say that his success in combating the arctic environment lies in his ability to avoid the extreme cold one way

It should be emphasized that in the case of human exposure to cold under field conditions it is usually a matter of combined exposure to cold and exercise or high level of physical activity This is true both in the case of the Eskimo and in most of our field studies where groups of men are made to live in bivouac in the field for different periods of time and when they in order to exist and to maintain their camp have to perform a great deal of physical exercise such as shoveling snow cutting wood etc This of course should be taken into account and future experiments should be so designed as to separate the two factors

I have already pointed out that it is characteristic for the Eskimo to maintain a steady even and rather moderate pace or level of activity just sufficient to keep himself warm without exhausting himself a level which he can maintain almost indefinitely due to his stamina achieved through training from childhood The same is true for the Lapps

The second point in the comparison of the condition in the rat and in the Eskimo is the food intake We found that the rat has a marked increase in food intake We did some careful individual food weighing in four different groups of Eskimos here in Alaska Barter Island Anaktuvuk Pass Kotzebue and Gambell These represented different diets different environmental conditions and different degrees of civilization the most primitive group being the Pass and the most civilized the

winter

TABLE XI

Average Consumption in Male Eskimos at Four Localities in Alaska

	Calories	Protein (gm)	Fat (gm)	Carbo hydrate (gm)	Calcium (mg)	Phos phorus (mg)	Iron (mg)	Copper (mg)	Vita min A (I U)	Thi amine (mg)	Ribo flavin (mg)	Nico tinic Acid (mg)	Vita min C (mg)
Barter Island													
Winter	3,800	160	164	418	980	1,800	19	2 6	3,445	1 2	1 6	23	22
Summer	3,700	157	176	380	930	2,064	24	2 2	3,388	2 0	2 0	34	34
Anaktuvuk Pass													
Summer	4,650	199	257	357	352	1,912	46	3 9	289	2 0	3 0	39	3
Kotzebue													
Winter	2,780	140	114	297	860	1,776	15	1 8	3,686	0 9	1 6	19	54
Summer	2,600	138	92	285	815	1,665	17	1 2	1,125	4 0	2 0	25	36
Gambell													
Winter	1,970	128	75	200	500	1,560	21	2 4	69,576	1 0	3 0	31	23
Summer	2,200	113	98	214	254	1,227	14	2 6	1,786	1 0	2 0	20	26
Mean	3,100	148	139	307	670	1,715	22	2 4	11,890	1 7	2 2	27	28

and summer, in the different families, by weighing everything that they ate, on separate plates, for about 5 days each time (15) We found that the adult male Eskimo s average daily gross consumption of approximately 3,100 calories was sufficient to maintain the body weight (Table XI) There was marked variation in caloric intake depending on food availability

On the basis of time-activity data, we estimated the daily caloric expenditure to be roughly 2,700 calories throughout the year There was no appreciable difference in the food intake between winter and summer These figures have been verified by more recent observations in this laboratory by Dr Drury (16) who found a mean daily caloric intake of 3,000 calories in two different villages

These figures are also in agreement with studies among Eskimos in Greenland where the caloric intake is in the order of 2,800 for adult males (17) They are also in agreement with our studies among trappers in Greenland (18) where the average gross consumption per man varied from 3,300 in the summer to 2 100 in the middle of the winter In a group of infantry soldiers in Alaska the gross consumption of calories varied between 3,100 and 3,400 per man per day (Table XII)

winter clothing and the greater energy expenditure required by moving through snow, etc On the whole, these figures are no higher than those reported for soldiers stationed in temperate climate

Burch What was the per cent of the calorie intake from fat?

Rodahl The percentage of calories furnished by protein fat and carbohydrate in the diet of the American troops living here in Alaska is not significantly different from that reported for United States troops eating a garrison ration in temperate or tropical climates (19) In airmen, however, we find there is an increase in the amount of calories derived from fat in the winter The Alaskan Eskimo diet is a high protein fat diet, but the amazing thing is that the amount of fat is not very much greater than that consumed by our soldiers and airmen living in Alaska As a matter of fact, the mean percentage of calories from fat in our whites here is 37 5 per cent as against 35 to 41 per cent in the Eskimo

Burch The reason I asked is that I remembered at Fort Churchill (Third Conference on Cold Injury) the Canadian group reported at least 60 per cent of the caloric intake as fat

Talbott Sixty eight per cent (20)

Burch Maybe there is a difference in the dietary habits between the

TABLE XII

Daily Intake of Essential Nutrients by Infantrymen and Airmen in Alaska

	Calories	Water (gm)	Protein (gm)	Fat (gm)	Total Carbohydrate (gm)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Copper (mg)	Vitamin A (I U)	Vitamin B_1 (mg)	Riboflavin (mg)	Nicotinic Acid (mg)	Vitamin C (mg)
Air Force Group														
I October	3500	1309	111	147	432	1115	1374	17.6	2.3	6748	1.8	2.3	20.0	32
II January	3000	1066	90	149	325	809	1330	13.8	3.3	5958	1.4	1.7	19.5	70
III April	2400	874	76	101	299	570	1135	14.0	3.1	7069	2.7	2.5	18.3	80
IV July	2900	1491	91	107	342	1191	1626	15.0	1.7	5530	2.8	2.6	19.6	113
Mean	2950	1185	92	126	350	921	1366	15.1	2.6	6326	2.2	2.3	19.3	74
Infantry Group														
I October	3300	1070	102	129	442	789	1416	18.6	2.5	4296	2.0	1.8	19.3	99
II January	3400	1123	103	139	432	1156	1751	19.5	3.3	9280	2.1	3.0	20.7	88
III May	3200	1309	122	126	412	1246	1735	16.8	2.3	4937	2.4	2.6	18.4	91
IV August	3100	1365	108	118	345	1004	1598	18.0	1.7	6270	2.0	2.2	21.4	128
Mean	3200	1217	109	128	408	1048	1625	18.2	2.5	6195	2.2	2.4	20.0	102

Reprinted, by permission, from Rodahl, K. Nutritional requirements in cold climates. *J. Nutrition 53, 575 (1954)*.

Alaskan Eskimos and the Canadian Eskimos The dietary habit would be on a cultural basis rather than on an environmental thermal one

Rodahl Don t you think that it depends in the first place on when you examine the diet second it depends on whether you mean total amount of fat or percentage of calories furnished from fat?

Burch I was referring to their report There may be a difference between the Canadian Eskimo and the Alaskan Eskimo

Rodahl It is hard to say

Burch I remember the report

Talbott It was a much higher percentage of fat

Rodahl Was it the amount of fat eaten or per cent of calories from fat?

Burch Percentage of calories from dietary fat

Rodahl The primitive Eskimo used to obtain about 50 per cent of the calories from fat and most of the rest from protein but I have not known of any figure higher than that So 60 per cent of the calories from fat would surprise me a little There is a tendency in the Alaskan Eskimo for reduction in the fat intake In many places it is quite noticeable We see the change from year to year

Talbott Reduction decade by decade generation by generation?

Rodahl Less and less fat

Hildes Is this being substituted by carbohydrate?

Rodahl Yes Incidentally I have noticed the Eskimos being referred to as fat or obese We find this is not true in the male Eskimo Obesity is very rare in the male He is extremely muscular We observed this during routine physical examination and during surface area measure ments It has also been verified by subcutaneous or skinfold measure ments by Elsner* in his laboratory

It may be concluded then that contrary to conditions in the rat there is no evidence of increased food intake in our Eskimos which can be attributed to cold exposure or cold acclimatization The reason is prob ably that our Eskimos are not exposed to such cold which would necessi tate elevation of body metabolism which again would necessitate in creased food intake

Carlson Could it also be that the activity is enough winter or sum mer so there is enough heat produced for what clothing they have? I agree with you about not comparing them but if the rats are run every day at 28°F they have a problem of heat dissipation If they are run in the cold room this is all to their benefit There would be the same food consumption in the two groups

*Elsner R W Personal commun cat on (Arct c Aeromed cal Laboratory Ladd A r Force Base Alaska 1955)

Rodahl There is no question of the relationship between the two As an example, the food intake of the arctic trapper is greatly reduced in the middle of the winter when he has to remain inside his cabin because of long periods of bad weather We found that his food intake went down to 2,000 calories (18) In the early spring his activity is greatly increased, and his food intake goes up During the break up his activities are again restricted, and his caloric intake is reduced

Kark Are you going to give us a breakdown of the kind of living and activities of the infantrymen that you studied?

Rodahl It has been reported in a technical report (15) from here

Kark The point I want to make is your values of 3,200 calories, and 13 per cent of total calories from protein are nearly the same as those consumed by troops in the tropics during World War II However, the values for calories consumed by soldiers in arctic regions, reported by Johnson, myself, and others (21), are much higher I think these need explanation They can be given I believe that the two situations Dr Rodahl and Johnson and I studied were quite different For one thing, the troops we studied did not have as good protective clothing as the soldiers have now And also, the type of activity and the exposure to cold were much more severe, I believe, than the ones reported here

For example, in the Musk Ox Expedition, fifty soldiers went from Churchill to Fort Nelson during 3 months in mid winter, they never had shelter except for a little while at Coppermine They were always in the open, in the barren lands, with high wind velocity and depressed temperatures They slept at night in the open, without any special kind of shelter

Rodahl This is a very important point, of course In our case, we were studying the soldiers as they were living and operating here, which meant they were out every day in temperatures even below $-30°F$ They were skiing, they were taking part in tactical maneuvers and performed cross country travel They were served food by a field kitchen and we were out there among them weighing the food and so on These were the normal activities of the troops we studied As a matter of interest, I may mention that Dr Rennie recently conducted an experiment in this laboratory with a group of airmen engaged in very heavy outdoor exercise They consumed 3,800 calories daily on an average

We have covered the ground, as far as the caloric intake in cold exposed man is concerned Let us now consider the metabolic response We pointed out that in the rat there is a rapid and marked increase in metabolism when exposed to 5°C It is well known that the so called basal metabolism of the Eskimo is markedly higher than that of whites,

when it is measured for the first time, in Eskimos living on the normal diet in their normal habitat

Several years ago we had the opportunity to study this problem in great detail, using four different Eskimo groups I mentioned this earlier *during the review of our nutritional study Over a period of 2 years we* made a total of 340 basal metabolism tests among 73 Eskimos of both sexes, here in Alaska In agreement with previous workers, we found that the basal metabolism of the Eskimo examined for the first time and on his own diet, is significantly higher than that of whites

[illegible] of this higher metabolism [illegible] that the high protein diet [illegible] per cent elevation, due to [illegible] factors were eliminated, the metabolism of the Eskimo was almost exactly the same as in white controls (22,23)

In this study we used the standard technique The subjects were very carefully selected on the basis of complete medical examination, to exclude any pathologic conditions, and the fasting was rigorously controlled We admitted the Eskimos to our quarters and had them sleep there for the night prior to the test, so we could be sure they were all under the same conditions In addition, we weighed the food prior to the night admitted, to get the protein intake and nitrogen elimination *Also, we carried out nutritional surveys among these people During* the actual test, great care was taken to avoid any disturbance, etc

Then we repeated the same procedure in the same subject day after day, at least 3 days running We used the Benedict Roth metabolism machine

We found that the average of the first test of all Eskimos, at all four localities, was 16 per cent higher than the DuBois standard The B M R was highest among the most primitive groups, such as the Gambell Eskimos and Anaktuvuk group, lower in the Barter Island *Eskimos, and lowest in the Kotzebue group When we repeated the test* on successive days, while they were still living on their own diet, we found, in some cases, a reduction of up to 20 per cent in the metabolism

Fremont Smith On each day didn t you make two or three runs?

Rodahl Yes

Fremont Smith Wasn t it always highest on the first run?

Rodahl Not always We found the metabolism to be rather labile in these peoples

Fremont Smith Doesn t the increase due to anxiety show up in a disproportion between the CO_2 eliminated and the oxygen absorbed? If you measure them both, wouldn t this show up right away?

Rodahl We did not measure the CO_2 except in a few cases when we measured both O_2 and CO_2. The old DuBois* standard was established on the basis of one and sometimes two tests He found later that his standard was about 6 to 8 per cent too high If you repeat the test you get the subject more completely relaxed

If we use an untrained, normal white subject, his metabolism is usually around ± 0 per cent of the DuBois standard, as measured with our technique here If we measure one of our laboratory technicians or colleagues, who are very familiar with us and our instrumentation, his metabolism is usually 5 to 6 per cent lower than the DuBois standard, even the first time

When repeating the test in the untrained whites on three successive days, as we did it in the Eskimos, we found that the B M R came down to an average of about 6 or 8 per cent below the DuBois standard This of course, has been observed by many workers in whites and untrained people

Travell This has also been shown in patients with myxedema (24) In a control series of tests the value obtained for the basal metabolic rate was apt to become progressively lower in later tests than in the first one This was all prior to thyroid administration of course

Rodahl Very interesting We were able to run two or three duplicate tests of 9 minutes length each time, and could observe the tracing as the test proceeded We kept on until we got good records with a smooth slope This has one advantage over the method where you analyze the oxygen content of the expired air, in which case you don t see what is going on, you get the mean for the whole period only In our case we selected, as a matter of routine, the lowest good records and compared those Even taking the mean of all duplicate runs we find the same conclusions are true but on a slightly higher plane

Burch You didn t give us the exact numbers, or is it 6 per cent below 0?

Rodahl Yes

Burch In other words, it is negative with respect to the DuBois standards?

Rodahl That is correct 0 per cent with reference to the DuBois standard was usually the result in an untrained person If you repeat the same test on 3 consecutive days, you find it comes down to -6 or -8 per cent, i e , 6 or 8 per cent lower than the DuBois standard

*Personal communication 1952 from E F DuBois of the Cornell University Medical College New York N Y

Burch The reason I raise the point is that it is stated that in acclimatization to a tropical environment, the B M R of the people of the tropics is lower than that of the people of the temperate or northern areas, but using the DuBois table, we find, in New Orleans, for example, the mean B M R is about −8 per cent Apparently, then, the B M R of the people of the tropics is not lower than that of the people of the arctic The DuBois standards are simply too high

Rodahl The fact that the DuBois standards are too high is now fairly well known

Horvath We teach this ordinarily to our students We tell them to ignore the old values

Behnke In Krogh s careful work he pointed that out also Krogh s standards are about 6 per cent less than those of DuBois (25)

Fremont Smith The interesting thing is that this is supposed to be very well known, and yet it has to be brought up again and again

Travell Even in the metabolism laboratory at the New York Hospital, which was DuBois , the standards have been revised downward

Rodahl DuBois was up here himself and did some of this work with us The need to revise the B M R standards is well established The trouble is, when scientists speak about basal metabolism, it is one thing, but when clinicians speak about it, it may be a different matter Basal metabolism studies have to be done very carefully

Behnke Would you give us the oxygen consumption or total calories per hour?

Rodahl I will give you all this later

Travell Are you going to tell us the lower limits of the distribution curve? What were the lowest basal metabolic rates, not the mean or the average?

Rodahl You mean absolutely the lowest?

Travell Yes

Rodahl Lower than −10 per cent, I think I remember one instance where an Anaktuvuk Pass Eskimo in his own environment had a B M R of 12 per cent higher than the DuBois standard He was brought to this laboratory and at the end of 3 days or so, his B M R came down to 9 per cent or 10 per cent below DuBois standard

Montgomery Did you run controls on non Eskimos in the same environment?

Rodahl Yes, I served as a control subject, and we ran my B M R both in the laboratory here and in the field Furthermore, we had the good fortune of having Dr DuBois with us, too He had collected data

for about 30 years on his own metabolism, and we were able to compare our finding here with his own in New York, and they were perfectly in agreement

In addition, one of the Eskimo groups that was brought in here was given large quantities of walrus meat after having lived on white man s food for a week, and we found a rise of the metabolism to 12 per cent over the DuBois standard while living in the same environment but eating their own food We tried to duplicate it in the whites but we couldn t, in the first experiment, because we couldn t get the whites to eat that much meat In a more gradual second attempt, this was achieved, and we had a rise of 13 per cent in metabolism

Montgomery How long after the walrus meat did you do the test?

Rodahl From 14 to 18 hours after the last meal

Burton Are you implying that the specific action of protein lasts 14 hours after the last meal?

Rodahl Krogh (26) found that the Eskimos, after a large meal of meat, eliminate through the urine only about 60 per cent of the nitrogen in the first 24 hour period This is quite amazing

Burton So, the curve against time for specific dynamic action is not the true curve for the Eskimo?

Rodahl At this level of nitrogen Furthermore, on such a high meat diet the intestinal flora are different, the rate of digestion and absorption may be changed It is known that the high meat meal stays with you a long time Isn t this a general observation?

Kark Would you tell us again what the percentage of protein is in the Eskimo s diet, per cent of total calories?

Horvath About 30 per cent.

Kark Of the ones you studied?

Rodahl Yes, but this varies with the seasons and from village to village We observed there was a distinct relationship between the B M R and protein intake, as well as the nitrogen elimination Thus, the highest B M R s were observed among the Anaktuvuk Eskimos, where the nitrogen eliminations were as high as 3 gm /hour, followed by the Gambell group and Barter Island and Kotzebue (Table XIII)

Blair Did you make any protein bound iodine determinations?

Rodahl I am coming to that In order to study the significance of the specific dynamic action of protein in the high meat diet with reference to the high B M R in the Eskimo, fourteen representative subjects from the four Eskimo groups were first studied on their normal native diet in the field, and then brought to our laboratory at Ladd where the B M R was again tested while the subjects were living entirely on white man s food We then found that whereas the average B M R in the

TABLE XIII

Average B.M.R. and Urinary Nitrogen Elimination

Location	B M R	N/hr, Fasting
Anaktuvuk Pass	46 3 cal/M²/hr + 16%	0 92
Gambell	42 9 cal/M²/hr + 10%	0 83
Barter Island	39 7 cal/M²/hr + 2%	0 66
Kotzebue	40 2 cal/M²/hr + 3%	0 62
Eskimos on white man s diet	− 8%	0 40

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field in this particular group had been +8 per cent and the nitrogen elimination 1 2 gm per hour, it now dropped to −8 per cent, and the nitrogen elimination was reduced to 0 4 gm per hour (Table XIV) Here I think the lowest is −15 per cent

Hildes How long did it take?

Rodahl It took 3 days I can t say this is all S D A Part of the variations may have to do with apprehension and the state of anxiety The state is rather labile, as I pointed out Often, after a few days, the Eskimos want to go home, they get restless and impatient and it may be difficult to achieve complete relaxation and good reproducible B M R records

Travell Is that the effect of successive tests?

Rodahl These are the final results In other words, after 3 to 5 days on our diet, these were the final, the lower figures

Travell Did you then put them on the native diet and do the test again?

Rodahl Yes We were able to persuade the Gambell group to bring some walrus meat to the laboratory At the end of the period on mess hall diet, we put them on walrus meat, and the metabolism went up to 12 per cent above the DuBois standard in this group

TABLE XIV

B.M.R. in Eskimos on Native and on White Man's Diet

Location	Subject No	Native Diet	White Man's Diet
Gambell	1	+11%	− 6%
	2	+ 1%	− 3%
	3	+ 1%	− 9%
	4	+10%	− 3%
Barter Island	5	+ 9%	−10%
	6	+14%	− 4%
	7	+13%	− 4%
	8	+ 6%	−14%
Kotzebue	9	−16%	−14%
	10	+ 8%	− 2%
	11	+ 7%	−15%
	12	− 6%	−13%
Anaktuvuk Pass	13	+14%	− 1%
	14	+12%	− 9%
	Average	+ 8%	− 8%

Reprinted, by permission from Rodahl, K Basal metabolism of the Eskimo J Nutrition 48, 359 (1952)

Fremont Smith By that time they were really impatient to go home

Rodahl This group was a little different They had never seen a tree before, and they seemed to enjoy their stay here very much

Burch How did they enjoy the white man's diet?

Rodahl Not much, they longed to go back to their own

Burch What did they not like about it?

Rodahl They didn t say Perhaps it was the way it was cooked

Burch Was there fat and seasoning in the food?

Rodahl In the first place the Eskimo usually boils his meat Our meat is usually fried I think there is a difference in meat too Caribou meat has a different taste

Fremont Smith There is another element bound to come in and that is familiarity It was unfamiliar Food habits are deeply entrenched in people and unfamiliar food is disliked because it is unfamiliar

Burch Did the food disturb their digestion?

Rodahl The food here would be much higher in carbohydrate We noticed they avoided lettuce and greens eating mainly meat

Hildes Did they take the same number of calories as before?

Rodahl Not as much because the activity was slightly lower but not significantly

Fremont Smith I think digestion is influenced by whether you enjoy or don t enjoy your meal

Rodahl The Eskimos are probably no different than human beings elsewhere in this respect

I must mention too that the 0 4 gm of nitrogen per hour in the fasting state in the Eskimo on our diet is the same as DuBois findings in whites He found 0 5 gm of nitrogen per hour in the medical student fasting 14 to 18 hours

I might also mention that we examined one Eskimo soldier living at Ladd eating our mess hall diet and he had a basal metabolism of 4 per cent lower than DuBois standard

Twenty RQ determinations in five Eskimos showed figures between 0 79 and 0 83 The body surface area was measured in 53 Eskimos and the height weight formula gave on an average 0 9 per cent higher results than the linear method

From these studies we concluded that there is surely no racial difference between Eskimos and whites in the basal heat production Apprehension and the specific dynamic action of protein are the important factors in the high basal metabolism generally obtained in the Eskimo examined in his native habitat On the basis of our data we have no evidence to suggest that there is an increased basal metabolism in the Eskimo due to acclimatization to cold

Burton I am still not happy about the implications of specific dynamic action lasting so long If you put one of the white men here on this high protein diet can you raise his basal metabolic rate? By that I mean under our standard conditions can you raise it this much?

Rodahl We did that in one experiment The first experiment was unsuccessful because the white subjects were unable to eat the same

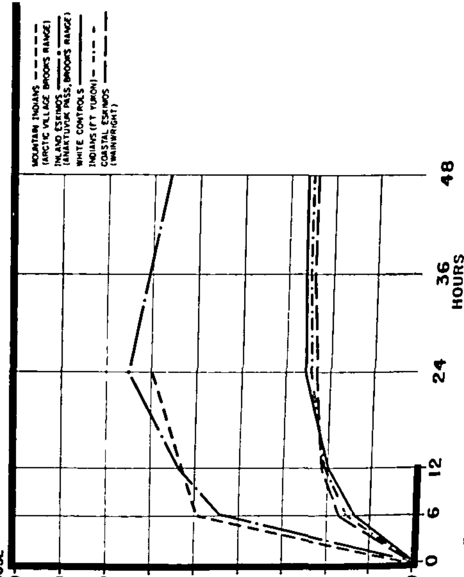

FIGURE 62 Thyroid I^{131} uptake in per cent of tracer dose in whites Eskimos, and Indians

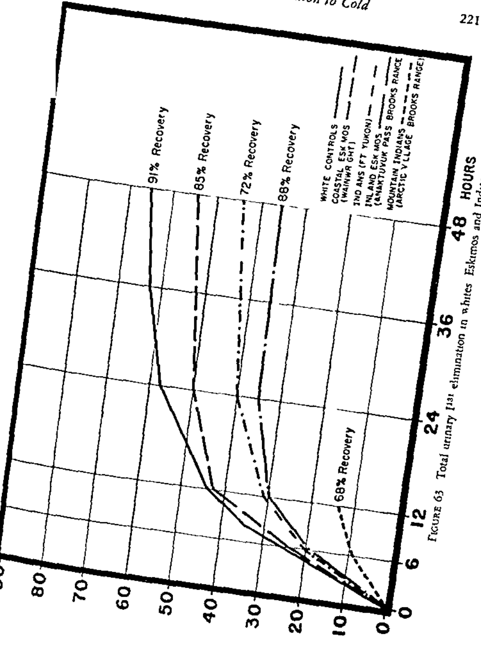

FIGURE 63 Total urinary I^{131} elimination in whites Eskimos and Indians

We have just completed a study where we took blood specimens 12, 24, 36, and 48 hours after the dose in the same subject, and found exactly the same pattern throughout In other words there was a slightly lower level in the native group, but this difference is not statistically significant The chemically determined PBI was about the same and well within normal range in all of these groups In fact, the mean PBI for the whole year in Eskimos was 5 9 mg per 100 ml as against 5 4 in whites

It may be mentioned in this connection that the mean blood cholesterol was about 200 mg per 100 mg in our Eskimo subjects (31)

Comparison of the results obtained in the same subjects during summer and during winter shows that there is no appreciable seasonal difference in iodine metabolism in whites, as evidenced by thyroid uptake, urinary elimination, and blood levels of I^{131} (Table XV) There is no evidence of any greater thyroid stimulation, as judged by the above mentioned criteria, in infantry men engaged in extensive outdoor activities than in airmen engaged in indoor activities during the winter Nor is there any evidence of increased thyroid stimulation in the whites at the end of the 4 week severe cold exposure as judged by the thyroid uptake, urinary elimination, and blood levels of I^{131}

When comparing winter values alone (Table XVI), we find there is no statistical difference between whites, coastal Eskimos, and Fort Yukon Indians in thyroid uptake, urinary elimination, and blood levels of I^{131}

dose They had abnormally low urinary eliminations and low salivary iodine concentrations (Figures 62,63) They also had rather low plasma protein bound I^{131} levels 24 hours after the dose This was associated with a high incidence of thyroid enlargement, and exceedingly low iodine intakes As a matter of fact, the iodine intake was probably of the order of 0 1 milligram potassium iodide daily Iodized salt has been used only occasionally, much of the available salt was noniodized salt and Eskimos do not use much salt anyhow Some of the families do not use any salt whatsoever

We find that the urinary iodine elimination was usually less than 100 γ/day When we gave these people 0 6 mg of potassium iodide daily for 3 months, there was a statistically significant reduction in their I^{131} uptake, on the order of 30 per cent

These findings are typical of endemic goiter as described by Stanbury

TABLE XV

I^{131} Metabolism in Whites at Different Seasons of the Year

	24 hr I^{131} Uptake	24 hr Urinary Elimination	24 hr Saliva I^{131}	24 hr Plasma I^{131}	24 hr PBI^{131}	PBI Count / Plasma Count x 100	PBI Chemical (mg/100ml)
Airmen							
Summer	23	56	15	1,3	1,0	78	—
Winter	23	66	12	1,1	0,8	70	5,7
Infantrymen							
Summer	29	59	21	1,2	0,9	74	—
Winter	27	58	11	0,9	0,6	68	5,7
Severe Cold Exposed							
Pre Exp	19	64	11	1,2	0,9	74	5,0
Post Exp	19	56	13	—	0,9	—	5,3

and collaborators (32) in the Mendoza population This condition has developed rather recently, *i e* since 1952 We did not observe any enlargement of the thyroid in 1951-52, but since that time at least three cases of toxic goiter have been recorded from the Eskimos at Anaktuvuk Pass, and at least that many from Arctic Village, out of a total of 50 or 60 people

The Anaktuvuk Pass Eskimos and the Arctic Village Indians are living under essentially the same conditions These Eskimos are deviating from the traditions of their ancestors In the earlier times, the inland Eskimos, the Nunamiuts, used to go down to the coast every summer to get seafood to barter with the coastal Eskimos, to hunt seals etc They no longer do so They stay in this mountain area continuously throughout the year

Hock In April 1948 I arrived in Anaktuvuk Pass the day the Eskimos first got there They had been nomadic until that time and they still are to some degree They had not been at Anaktuvuk for some

TABLE XVI

I^{131} Metabolism in Whites, Eskimos, and Indians During Winter

	I^{131} Uptake Per Cent of Dose Hours			Total Urinary Elimination Per Cent of Dose Hours			Recovery Hours		Plasma I^{131} Per Cent of Dose	PBI^{131} Per Cent of Dose	Saliva I^{131} Per Cent of Dose	PBI mg/100ml
	12	24	48	12	24	48	24	48				
White	16	25	26	31	62	63	87	90	1 0	0 7	11 6	5 8
Coastal Eskimo	17	23	24	25	50	54	74	78	0 6	0 4	8 1	5 5
Ft Yukon Indian	22	38	37	23	48	53	86	90	1 2	1 1	8 2	6 3

years Apparently this was a game conservation mechanism they used At any rate, shortly after that time the post office was established at Anaktuvuk Pass and they have become stationary since that time Some of the older men still take long hunting trips with their families for a month or longer away from Anaktuvuk, but the majority of the population stay there

Rodahl This has happened since 1935 They left the coast at the mouth of the Colville River in 1931, came up to the Killik River, and eventually moved over to Anaktuvuk Pass and have stayed here ever since Their diet is essentially caribou meat An analysis made by Dr H F Drury in this laboratory showed 0 1 γ iodine per gram caribou meat collected at Anaktuvuk Pass

Burch Several of you have mentioned the fact that the Eskimos have settled around a post office Do the Eskimos first remain in an area after which a post office is established or is a post office established first Eskimos accumulating in its vicinity later?

Irving They were being attracted to that region by the fact that it was on a mid-course of air route to the Arctic, and there were occasional aircraft stops being made So they had come to reside there a little more regularly than had been the case However the establishment of the post office was merely recognition of the inclination to stop where there was going to be traffic and communication

Burch The Eskimos accumulate in an area first?

Rodahl Yes

Talbott What is the altitude?

Rodahl It is 3 000 feet above sea level Altitude is known to stimulate the thyroid but we feel this is an obvious case of endemic goiter

Burton Are there fish in the region?

Rodahl Yes, fresh water fish

Burton Sir Charles Hercus (33) of New Zealand said there is a great deal of goiter in the interior of that country He discovered that the fish had obvious goiters That might be worth looking into

Rodahl Yes In fact, someone suggested we look into the caribou as well The trouble is the caribou run too fast for us to do I^{131} uptake experiments on them! We certainly can examine them dead, however

These data on the endemic goiter among the inland Eskimos and the Arctic Village Indians are by products of our study of the thyroid function in men exposed to cold We are recommending to the Public Health Service that they give these natives iodine Incidentally, I might also mention that we have seen thyrotoxicosis in one coastal Eskimo

On the basis of these studies we feel justified in concluding that the thyroid does not seem to play any significant role in human acclimatiza

tion to the arctic environment when the cold stress is no greater than what is normally encountered by Alaskan Eskimos or Indians in the course of their normal life or activities, or by soldiers engaged in usual arctic service

Carlson There is one report by Bass (30) which indicates when there is severe cold the thyroxin utilization is increased

Rodahl This is the report I referred to in the beginning, by Ingbar, Kleeman, Quinn, and Bass (30) Exposing the almost nude man to 13°C for 12 days, they did find increased utilization of thyroxin As I said earlier, our men are not exposed to that kind of cold

Horvath That is intermittent exposure, not continuous?

Rodahl Almost continuous, I understand

Carlson They have done two experiments, I think

Hildes How did they measure their utilization?

Carlson They tagged the thyroxin

Hildes Dr Rodahl s observations don t include thyroxin

Carlson Yes, they do

Rodahl We determined the total plasma I^{131} and the PBI^{131}, so we get the conversion factor

Carlson Did you follow it long enough? It must be followed for days

Rodahl For 48 hours

Hildes At 48 hours the conversion ratio has a large margin of error

Rodahl When it comes to blood values I am always a little skeptical because of the small difference between the actual values and the back ground count We have a low background count here, but we have to give rather high doses 50 microcuries I don t know how reliable these blood values are It is interesting that all of our natives, who are more cold exposed than we are, do have lower PBI^{131} than our whites although the difference is not statistically significant This would tend to support the possibility that it is an increased utilization But it could also mean the opposite—a slow discharge of thyroxin

Carlson In rats, conventional methods did not indicate an increased iodine turnover Only a complete turnover procedure demonstrated this (34)

Rodahl We are just completing this study Dr Bang is out at Point Hope now, he sent me the final results a couple of days ago There is no statistical difference The interesting thing is, also, if you take the PBI^{131} in whites, it is slightly lower in the winter than in the summer but, again not statistically significant So, this should probably be looked into further

Carlson That is one of the things that interested us because if the

control systems are working, then the PBI will never get low You will get an increased production or turnover You always have to look for turnover When you have a normal control system, the PBI just isn t going to drop

Rodahl How is it, then, with the increased S D A? Does that require thyroxin? If so, you expect a greater utilization in the Eskimo, if he has a higher S D A

Carlson The whole question of utilization is, I think, an unknown in terms of thyroxin

Rodahl This, of course, is something in which we are very much interested In summary then, I think it is fair to say that the statement so often found in textbooks, that people who live in cold regions have an increased metabolism and, therefore, consume more food, is not necessarily true, nor is it true always to say that people living in northern climates have a higher fat consumption than elsewhere In some cases, yes, but not always

Then the next problem we have been interested in is that of physical fitness We pointed out that the success of the surviving rat at 5°C is on the basis of its ability to maintain a high level of metabolism We have pointed out that the Eskimo can do this, too, because he is physically fit He has the stamina which he has achieved from childhood, by training

As a matter of fact, Dr Rennie made some measurements of the state of physical fitness of some of our Eskimos when they were in this laboratory a few years ago serving as subjects for our comparative sweat study Incidentally, I might mention here that it would be reasonable to assume that a favorable adaptation to a cold environment would be a reduced tendency to sweating during moderate heat loads which would permit greater body heat storage and reduce the adverse effect of excessive sweating on clothing insulation We found this was not the case (35)

In the course of this study, Dr Rennie measured, by the standard treadmill test, physical fitness in a group of Eskimos compared with a group of selected, well trained Army soldiers and a group of average airmen He found that the ratio of physical fitness in the Eskimo the Army soldier, and the airman was of the order of 3 5 2 5 1

Fremont Smith What physical fitness test was used?

Rodahl The treadmill test described by Johnson *et al* (36)

Rennie This was the treadmill fatigue test (36) in which the individual runs at a pace of 7 miles per hour on a treadmill inclined at an angle of 8½ per cent The test is designed for a 5 minute run, or until the runner is exhausted, whichever is shorter Pulse rates are

measured at selected intervals after the run We extended the time of running to 10 minutes because all the Eskimos could run the 5 minute test without difficulty and we wanted to increase our spread of fitness indices

Fremont Smith Were you content that the test seemed to represent what made sense in general physical fitness?

Rennie I believe that it separates a well-conditioned man from a poorly conditioned man I do not think it will separate shades of gray one from another as far as physical fitness because the motivation factor becomes increasingly important

Horvath You only measured physical fitness for that level of activity

Rennie That is right

Fremont Smith I am glad you brought in motivation It always enters crucially into this kind of test

Rodahl To give you an idea the Eskimo subjects ran until we asked them to stop at the end of 15 minutes They jumped off and sat down to a meal as if nothing had happened The soldiers were so fatigued that one of them had to lie down for a couple of hours after the run

Rennie He was highly motivated His commanding officer was in the room

Fremont Smith This proves your point Perhaps it didn t make enough real distinction

Behnke I think the motivation factor can be evaluated in tests of muscular endurance of these Eskimos from the pulse rate level

Rodahl We made some tests

Behnke In individuals who are really trying and who run to exhaus tion the pulse rate will be of the order of 160 or let us say above 140 In a simple step up test where individuals continue to exhaustion the average length of time that normal cadence could be maintained would be 90 seconds for the average Navy man Professional baseball players would go 2½ minutes but their pulse rates would be only 120 com pared with 140 for the Navy men That is to say the Navy men were trying harder but the baseball players had more endurance Whenever they felt a little tired they stopped because it was the old story they were saving themselves for another day of baseball

Fremont Smith How about the hemoglobin?

Rodahl It was definitely lower in the Eskimo

Hildes How much lower?

Rodahl In the order of 7 per cent (37)

Fremont Smith They have to circulate blood and overventilate to get the same amount of oxygen in

Burton The index of the total ventilation to the oxygen consumed

is being talked about as a measure of efficiency, but it is extremely easy, by simple algebra, to show that all this measures is the pCO_2 level which the homeostatic mechanism keeps* Obviously, this must be different in the Eskimo I think it has nothing to do with efficiency

$$E \approx \frac{O_2}{V}$$

Multiply top and bottom by the R Q (CO_2/O_2)

$$E = \frac{CO_2}{V \times R\ Q} = \frac{\%\ CO_2}{R\ Q} - 100$$

[illegible]

Fremont Smith Would it have to do with hemoglobin?

Burton It is modified by the R Q It turns out this is a measure of the pCO_2

Fremont Smith With anemia, wouldn t they have increased ventilation for the same amount of oxygen supply?

Burton No, I don t think so

Meehan A couple of years ago we did some physical fitness tests on various people from the University of Southern California Some of our subjects were trained athletes For example we had some people from the football squad, the track squad, and some swimmers One thing that struck us in these athletes was their ability to tolerate a high alveolar pCO_2 over a longer period of time than the untrained, average university student

Horvath Is this a standard exercise test?

Meehan We were using the Harvard step test

Horvath Exactly the same thing The Harvard step test was a modified form of the field test

Meehan One of the things we observed was that the trained athletes would work longer, that is, the duration of their exercise would be longer, but they would have, for a longer period of time a higher alveolar pCO_2 than did the other subjects

Rodahl Whichever way you look at it, the Eskimos are more fit than the white They can keep trotting behind a sled all day, and it doesn t bother them This difference in fitness is important for it is a factor which may determine life or death in many survival situations where the temperature drops to levels where one has to keep active in order to survive This the Eskimo can do if he is caught without a sleeping bag

*So called Ventilatory Efficiency = O_2 consumed/ventilation

by [illegible] on his sled He will sle[illegible] the procedure is repeated As already pointed out, in temperatures lower than −40°F there is no way we can keep an inactive flier or soldier in thermal balance for a long period of time, except by intermittent physical exercise in order to increase heat production

Kark How much energy cost is there in maintaining that kind of physical fitness? How does this fit in with dietary intake of 2,900 calories?

Rodahl This would be necessary only on rare occasions in the Eskimo The Eskimo will travel and hunt and sit quietly for a long time, waiting for the game This he can keep up for several days without much effort

Travell How does he maintain his physical fitness?

Rodahl He starts his physical conditioning in childhood and keeps it up throughout life

Fremont Smith Eskimos don't lose their training even through an interval of rest, whereas we probably would

Rodahl That may be At the same time they are probably more efficient When an Eskimo moves over tundra, he probably does it in a much more efficient manner, because of his experience His movements are more efficient

Rennie What I believe Dr Kark meant was that the high level of physical fitness observed in the Eskimo implies a good deal of sustained physical activity and a high caloric intake The latter was not observed What level of physical activity is required to maintain physical fitness once it has been attained? It would be of interest and importance to know this

Horvath There is a paper by Knehr (38), in which this was being done with a group of Harvard men over a period of around 6 months to 1 year I don t remember the figures exactly But there isn t too much one has to do to maintain a state of physical fitness once it has been attained The point, of course, is if the state is lost, then, as always when trying to return to this high level of fitness, there is a certain amount of difficulty

Rodahl This is very important I have seen this in people skiing and marching During the war we used to walk 30 kilometers every Saturday This march, once a week, apparently was enough to maintain a high and steady level of physical performance I also think that it is important that one acquire certain skills, such as skiing, early in life, in order to attain a high degree of efficiency I am sure one who knows

how to ski will use much less energy than one who doesn t because the latter is using the wrong muscles All this must be taken into account when talking about energy requirement

Horvath Dr Dill who participated in every one of the tests could maintain a level of physical fitness as far as the test was concerned which was superior I know in many cases to mine although I am sure he was at least 20 or 30 years older He was in much better physical shape because he was engaging in this kind of activity

Rodahl All you need to do is to see a 75 year-old Eskimo drum dancing and you will be convinced he has something you don t have

Travell When the Eskimos run behind the dog teams does some of their momentum come from the sled? Do they hold on to the sled?

Rodahl Yes they do it the easy way They stand on the sled until they get cold then trot along they may stand on the one sled runner with one foot and kick with the other and so on They turn around so the wind doesn t bother them

Travell With both variety and economy of muscle movement?

Rodahl Exactly To him dog driving is fun He will probably sit in the house and enjoy himself day after day until his wife complains there is not enough food and he has to go out and get it He may accomplish this in a day and that is all I think one would be misled if one thinks that the Eskimo is maintain ng this high level of activity all the time But he does it enough to keep fit

Talbott This high degree of physical fitness is similar to that of the natives in the Andes who certainly for generations from birth are able to do a tremendous amount of physical work Their caloric intake is con siderably less than that of the white man who went in for short periods of time yet the amount of work they can do is twice or three times what we can do They eat very little sometimes every 24 hours

there is a tendency toward this kind of attitude in the United States also And you will certainly find that organized physical training is common in most native groups The Aleuts for instance have used

They

took

oung

boys were taught by the older men to stand bent in cold water so that both legs and hands with the forearms were immersed in order to

enure them to hardship and cold* Both in the coastal and inland Eskimos, the young boys are exposed early to cold, hardship, and physical training As I mentioned, the young boys are often taken out hunting when they are 8 years old, and are made to take part in the struggle for life This was common practice among the coastal Eskimos at Wainwright, for instance The women at Gambell St Lawrence Island were not permitted to wear mittens Whatever they did, they did with bare hands

We also know that the Tlingit Indians used to break the ice and swim about in ice water, as a regular toughening up procedure †

The Finnish Sauna bath is commonly used also in Norway and Sweden Some people think of it as a torture chamber I think of it as a method of exercising the peripheral circulation The room temperature may rise to 170°F you relax on a bench with your feet up in the air The vasodilation is so great that you sometimes can hardly stand the pain in your toes Then you go into a cold shower and cool off gradually

There must be something to this because all the famous Finnish racers and skiers use the Sauna regularly Comparatively little physiologic work has been done on the effects of the Sauna We have been fortunate to have a Sauna constructed here We are planning to do some organized physiologic work in it

It is quite obvious that in discussing human acclimatization to cold the factor of exercise must be considered As I pointed out, very often in our experiment we have a combined effect of exercise and cold exposure, and it is quite conceivable that some of the changes we observe in the natives exposed to cold—

Horvath This applies to the men in the heat The more physically fit, the better off they are as far as certain aspects of the acclimatization process are concerned

Rodahl If the Sauna is a factor, you could conceivably achieve acclimatization to cold by applying heat

The significance of the state of physical fitness in tolerance to cold has been emphasized already by Adolph and Molnar (39) It is quite conceivable that many of the changes that are brought about by physical conditioning and training may form part of the so called acclimatization complex

Summing up the changes as we know them, it may be stated that training increases the muscle mass causes increased vascularization of

*Milan F Personal communication (Arctic Aeromedical Laboratory Ladd Air Force Base Alaska 1957)

†Marsh G H University of Alaska Personal communication 1957

muscle tissues, and increases the over all metabolically active mass The total blood flow is increased by the greater cardiac output Because of the dilated muscle arterioles, more blood flow is diverted through the active muscle in exercise It should be noted that Heroux (40) also observed increased vascularization of muscle tissues in cold acclimatized rats

It appears to be quite obvious that we should consider these two fac tors in future experiments of this kind

Let us now turn to the question of the possible mechanism for the generalized acclimatization to cold This is, no doubt, a subject which would be worthy of some discussion

Isn t it quite fair to say that acclimatization to cold should be bene ficial to the organism, and that the objective of cold acclimatization would include such alterations which would favor maintenance of thermal balance in certain types of conditions and also, increased oper [illegible]

The Australian aborigines apparently, according to Hicks *et al* (3,4), achieve such a conservation of body heat by effective vasocon striction and the toleration of reduced peripheral temperature While [illegible] sm of cold acclimatization [illegible] *order to maintain a high* [illegible] 4) reported a marked drop in both central and peripheral temperatures in the aborigines

Fremont Smith Those were the mouth temperatures you mentioned?

Rodahl Yes

Fremont Smith They could be confirmed with better observation?

Rodahl Yes, but, at the same time, they were taken morning and evening in the awake state, so there shouldn t be too gross an error

Fremont Smith You are quite convinced that the central body tem perature does drop in the aborigines?

Rodahl Yes, I feel so on the basis of Hicks data

Burton Are you taking the oral temperature as being the central one?

Rodahl No, we discussed this at the Cold Physiology meeting in Copenhagen in 1950 You and Dr DuBois agreed that the oral temper ature represents roughly 20 per cent external and 80 per cent central temperature That is why I say specifically oral temperature At least it is close to central temperature

Returning to the comparison between the aborigines and Dr Carl son s hypothesis, one wonders whether the difference may be a question of different degrees of the same phenomenon considering the prolonged

cooling of the sleeping aborigines In view of the fact that the aborigine can rely on the sun to warm him in the morning he can afford to allow himself to be cooled, providing he has accustomed himself to stand this drop in temperature LeBlanc (41), however, observed the same drop in skin temperature in both acclimatized and nonacclimatized men, but he observed a greater drop in core temperature in acclimatized than in nonacclimatized persons exposed to standardized cold stress, which indicates that the *maintenance of the core temperature is not so* essential in cold acclimatization, after all

Scholander has, in several of our discussions, emphasized the need to study the critical temperature in exposed and nonexposed people as a criterion of acclimatization to cold It appears that we may be dealing with something different here Isn t it true that the critical temperature is defined as the point where metabolism has to rise, in order to maintain body temperature? If you disregard body temperature, you may find another ambient temperature at which the metabolism will begin to rise although the body temperature has fallen This of course approached the semihibernating state you talked about earlier

The aborigines in Australia adjust themselves to suffer the cooling without shivering, without a rise in metabolism, and without waking up This is a most remarkable phenomenon

Fremont Smith We do the same thing in sleep, also, only to a much less degree Our body temperature goes down, and we don t shiver We do a little more sweating, and our temperature is down perhaps 1 or 1½ degrees They go down 4 5, or 6 degrees But it is the same process, perhaps That is why we go back to the question of the relationship between sleep and hibernation

Rodahl Except you may question the cause and effect In sleep, your metabolism is lowered and, therefore, your temperature falls The aborigine s environment is so cold, it cools his body It may be that this is the difference If you took an aborigine into your home and made him comfortable, he might react the same way we do Of course, when we are sleeping, we are fairly well protected are we not? Isn t that the difference?

Fremont Smith In order to get our temperature down, we have to do a little more sweating He doesn t have to sweat, because he has a cold environment to deal with It seems to me it doesn t necessarily make a difference In both cases, the metabolism goes down and no shivering or increase in metabolism takes place, where you would expect it to if the thermostat had been set at the higher level

Rodahl That is right The remarkable difference is, though, that while we would start shivering and wake up, the aborigines apparently

let themselves go into a state of semi hypothermia The aborigine can afford to, because he knows the morning is going to come, the sun is going to rise and with it the temperature is going to rise to 33°C in the shade, and he is going to warm up

Fremont Smith Does anybody know if environment of a normal sleeping person were gradually cooled, could he be brought down to a lower body temperature without shivering, than would be possible if he were awake?

Rodahl This I believe is possible

Fremont Smith This would fit in

Burton I am puzzled, and I am not aware of the data on which you are basing your remarks, Dr Fremont Smith, about the temperature in sleep

Fremont Smith You mean in the normal situation?

Burton Yes The change in skin temperature is very slight, from what I know

Horvath It goes down to a degree

Behnke It is 1½ degrees on many men

[illegible]

I was there, wearing thermocouples but there was no evidence of vaso dilation in sleep Has it been proved there is actually extra sweating in sleep?

Fremont Smith I thought it had Your data were on children, perhaps they would be a little different in adults Do you have the information Dr Horvath?

Horvath I do not have it but I know we have studied it I don t think we ever did find there was any change in the amount of sweating or amount of sweat produced There is a gradual weight loss which you can attribute to the metabolic level

Burton [illegible]
studied th [illegible]
missions [illegible]
little sleep, his temperature came up, instead of dropping Apparently in the case of tension or fatigue, what happens is the reverse of the normal

Fremont Smith I can well believe this

Rodahl Isn t it true we don t know much about sleep anyhow?

Fremont Smith Practically nothing

Rodahl I understand the metabolism goes up during the first hour of sleep and from then on it gradually drops

Covino Dr Hammel visited our Laboratory recently and told us about the experiments he conducted with Dr Scholander (42) in Norway in which they had men continuously exposed to cold These men while sleep [illegible]

Covino I don t know he didn t say

Fremont Smith He probably would have those data?

Covino He said these men were shivering while sleeping

Horvath They show the same cyclic temperature as though they were out in a normal environment

Fremont Smith At a lower level?

Horvath At a slightly lower level

Covino They do differ from the aborigines

Horvath That I think could be questioned No one knows whether these did or didn t shiver We have talked about this before I don t think his data are precise enough to tell us whether or not they shivered He talks about one case having a fire by the left hip and the next case by both hips

Fremont Smith Weren t Scholander s men sleeping alone?

Rodahl According to Hicks *et al* (3 4) the aborigines slept two together with at least three fires

Fremont Smith And the men close together?

Rodahl Sometimes even more of them huddled Hicks is very emphatic about the absence of shivering Someone ought to go back and look it over with better equipment

Fremont Smith Maybe if they put out the fires and let the temperature go down they would shiver

Behnke Some rather interesting experiments were carried out by Dr Kleitman (43) on submarine personnel with respect to the diurnal variation in temperature with reference to the change in watches It was found that individuals sleep when the body temperature is low If the watches of submarine personnel are changed so that they are rotated the diurnal variation in temperature is abolished If however a week or more is allowed to elapse then the individual whose temperature previously was low at night now becomes elevated at night Adjustment to a new cycle takes place and again the diurnal variation is seen

Fremont Smith So the relationship of low temperature to sleep is maintained even though the diurnal is reversed?

Behnke One of the causes of fatigue was the fact that individuals were trying to sleep when their temperature normally would be high This was compensated for in the Navy by drinking more coffee

Carlson Isn t this contrary to this point? Because it says that there is a diurnal variation If I try to sleep during the day, my temperature doesn t drop

Behnke Until you get adjusted to a new cycle

Travell In other words, it is not an essential criterion of sleep, it is something that follows sleep

Horvath Not all of Kleitman s (43) subjects did this Some of them refused to cooperate with his general pattern, and they retained the same cycle that they had before So that their temperatures even though

did when

We have

pecifics

fires gone

out and the ambient temperature dropped, possibly shivering would have begun in the Australian aborigines I discussed this problem very recently with Dr J S Hart of the Canadian National Research Council Laboratory in Ottawa Dr Hart is going to Australia in a few months

o

ing would begin

Fremont Smith The shivering thermostat was set low

Rennie The rate of change of skin temperature during normal sleep under blankets may be so slow that fewer thermosensory impulses are evoked, even though the absolute level of skin temperature is reduced This would reduce the shivering drive quite apart from any change in the set of hypothalamus

Horvath Not that I want to disagree but I know when we ran a similar sort of experiment years ago With people in the nude, at +15° and +10°C there was considerable drive to shiver In such a situation, when you are asleep, you wake up shivering

Rennie That is a different situation from normal sleep The rate of change of skin temperature may be quite great under those conditions I am referring to this diurnal correlation between sleep and body temperature as being a result of less active peripheral thermoreceptors consequent to relatively slow changes in skin temperature

Horvath This is when it was falling

Fremont Smith He is saying that if you make it fall very slowly, you get less sensory impulse, and sensory impulse is always determined, I think, by rate of change

Rennie Among other things

Burton I should like to introduce another consideration that shivering is, after all, defined as a manifest tremor brought on as a defense against cold That definition does not include all of the defense against cold which the muscles give you In other words if an electromyograph is used, it is found that there is an increase of muscle activity which has not yet reached the point of coordinated shivering So, until this is done with the electromyograph, it might be said that they didn t shiver, but I wouldn t think he had proved that they didn t have an increase of muscle activity or of muscle tension

Rodahl It would be uneconomical for the aborigines to shiver, being nude, they would lose heat by convection very fast

Burton The other factor relevant to this is that in going over records of shivering men in which we had the electromyograph simultaneously with the shaking of the bed, we discovered that what psychologists would call psychic factors tremendously affect the appearance of tremor The relationship between the muscle activity and whether it is [illegible]

Blair May I interrupt with a possible pseudoscientific explanation One of the most fantastic physiologic phenomena I believe, is the described behavior of the Yogis in India, who are supposed to have developed some degree of control over sympathetic responses Where sympathetic responses are discomforting or interfere with rest or sleep, the Yogis supposedly have gained some degree of control over those sympathetic nervous system activities

It is possible that shivering is so discomforting and interferes so much with sleep and rest that the aborigines through many generations have become able to inhibit shivering at will Thus, absence of shivering may be a voluntary action to increase rest and comfort under certain prevailing conditions

Montgomery There might be an important cortical factor in the Eskimo

Rodahl *I think it is too early to say much more about it*

Irving Scholander and Hart* are peculiarly curious about this situation because they don t think the present data are sufficient for description let alone for speculation upon what may be in operation In other words it seems to me the data which Hicks (44) presented are not sufficient for more than a speculative view

Rodahl That is all they are sufficient for, but they are extremely interesting as such

*Personal communication

Irving It is a nice possibility

Behnke The startling fact that deep body temperature falls without the individual s awakening, as reported in the aborigines, is something which has not been duplicated in any test we have made on acclimatization We have never been able to acclimatize individuals, and then drop the temperature slowly so that their deep body temperature falls during sleep

Rodahl I assume you will discuss that further The final point I was hoping to bring up was local acclimatization but I am sure this will also be discussed It would be of interest in connection with the discussion of the aborigines to bring in the warm hand of the Eskimo In this respect the Eskimo may differ from the aborigine, inasmuch as he has a warm hand from which he loses a lot of heat This, of course, is not an advantage for the Eskimo in terms of thermal balance yet it may be in his interest as far as manual dexterity is concerned

Fremont Smith And losing heat during exercise

Rodahl Yes

Fremont Smith Is his hand warmer for a given level of cold environment than that of the white man? We haven t had those data

Rodahl Dr Meehan s work was done indoors (28) I don t know whether we know enough about the effect of the thermal state of the Eskimo on peripheral circulation I would be interested in knowing if he maintains a warm hand when he is thoroughly chilled or whether that is just a result of the excess heat he has to lose anyway Perhaps Dr Meehan can give us the answer?

Meehan I will not make comment now because I am going to talk about it later, in my presentation

Carlson We found that we could bring this change about by continuous exposure, though additional negative heat load will cause peripheral vasoconstriction This readjustment does not involve a great heat loss since the hands are but 5 per cent of the body surface An increase of 10°C may require only a 0 5°C drop in trunk temperature to make up the difference (45)

Rodahl Except in cold water, it would be more

Carlson Water is a quite different problem

Rodahl Certainly in the Aleutians this is important

There are two obvious explanations for this warmer Eskimo hand One is that the Eskimo has more heat to lose in other words his skin temperature *is higher because of the higher metabolism* There are a number of points which seem to indicate that this is the case

At the Third Conference on Cold Injury, Coffey (46) reported on his studies of Eskimos living on a white man s diet while working out

doors It appears from his work (46) that the Eskimo has better manual dexterity than the white even when his finger skin temperature is equally low as that of the white

Burton I should think the nerves continue to conduct impulses down to lower temperature

Hildes Our approach to this is to use one hand as a control against the other

Rodahl That is not quite fair because some people use the right hand better than the left

Hildes If you have a few subjects and mix them up between dominant and nondominant, it can be demonstrated that resistance to finger numbness can be increased in one hand as compared to the control hand just by exposing that hand, which then has nothing to do with metabolism

Rodahl This is exactly what I was going to say We pointed out the one possibility is that he has more heat to lose, *i e*, a warm body can afford to lose heat through the warm hands The second possibility is that the observed differences in the natives are conditioned by training and accustomization resulting in a modification in the cold pain threshold, or a modification in the vascular response to cold stimuli Conceivably the answer lies in a combination of the two possibilities Takahashi (47) has demonstrated that training produces changes in the circulatory response to cold exposure When one hand or foot was cooled in ice water for about an hour once or twice daily, the skin temperature after ten exposures rose more rapidly following the initial drop Voll, according to Hensel (48), exposed the foot to water of 10°C daily for 15 minutes and observed a desensitization against cold that occurred only in the exposed limb and not in the unexposed

Montgomery Is the skin temperature of the two hands equal before immersion?

Rodahl I don t know

Montgomery It would be interesting to know whether the skin temperature is equal in the two hands before immersion, that is in the hand previously repeatedly immersed and in the control Then it would seem important to know the change in temperature of each hand during immersion and the concomitant sensations and dysfunctions of each hand

Rodahl We felt it is very difficult to put our finger on any specific real evidence of general acclimatization in people exposed to the kind of cold we see here under natural conditions There may be some clear cut evidence of local acclimatization, however We thought that the warm Eskimo hand repeatedly described by arctic travelers is a good example We felt that there were two obvious ways of explaining this phenomenon First, the Eskimo apparently has more heat to lose

morals, and to cultivate to improve or develop by study, exercise, or training

This, as I see it, is exactly what takes place in the successful inhabitant of the North

Talbott Dr Burton you criticized the term accustomization in your book (8) Are you going to accept cultivation as a substitute?

Burton Yes, I like it a lot better It is a perfectly good dictionary word isn t it? As long as you don t make it culturization

Fremont Smith Isn t culturization used in the same sense?

Burton You spoke of evidence that the threshold of pain to heat in the Eskimo is different What do you think of the admittedly slight evidence that Brown (54,55) had that the threshold for injury by heat in a couple of Eskimos was very different from that in their other subjects? They were doing a study of the blood flow of the forearm in them selves and everybody has done this routinely on whites in their own laboratories At the high temperature end of the range they used 45°C baths to cause maximum blood flow, which is quite routine in our labo ratories When they did this on two Eskimos their arms came out in blisters I do not think this has ever been seen in our white subjects down south

Rodahl I should like to point out the possibility of the individual differences Colonel Blair (56) has shown that in some rabbits you can induce frostbite while in others you cannot I wonder if the difference in the reaction to the water bath you mentioned could be a result of individual variations rather than racial differences

Burton They naturally did not continue with the 45°C with the rest of the Eskimos because they did not want to prejudice their cooperation So they had only these two Then they had to decide they would use 40°C as the highest temperature

Rodahl This is interesting but doesn t it also point out the impor tance of tissue adaptation to cold?

Burton Yes

Meehan I have seen the same phenomenon in people of Japanese extraction in the Los Angeles area

Fremont Smith Blisters at 45°C ?

Meehan Yes

Behnke You may have a test for cold acclimatization by heating Dr Burton It is interesting that the point at which proteins coagulate and the heat necessary to produce injury constitute a critical level which is very finely set at about 45°C or a little higher I mean that this range is extremely narrow for individuals in temperate zones

Fremont Smith Won t blood flow come into it? The faster a person

can adapt by pouring blood through the arm the greater the protection he would have against overheating of the tissues immediately above the blood vessels

Burton In this case it is in a well stirred water bath The tempera ture of the skin is practically forced to be that of the water no matter what the blood flow does

Fremont Smith You mean if you cut off the blood circulation it wouldn t make any difference?

Burton In this experiment the temperature of the skin is forced to go to 45°C in spite of what the blood flow does

Burch How deep would you say? The skin is quite vascular

Burton Yes I am not speaking at all about the gradients The blister is superficial

Burch

Burton

Fremon

We don t know how deep your heat has to go to produce injury

Burton This was superficial injury a blister

Montgomery In the Gibbon Landis (57) vasodilatation test when hands are immersed to above elbows in 45°C water for an hour we have seen no blistering of hands having intact circulation

Burton This is my point This test is a rather routine one

Montgomery How long were the hands in water?

Burton I think it takes a minimum of 20 minutes to measure the blood flow to their satisfaction however this is published (54 55)

Behnke Why 45°C ?

Burton This is a standard test for blood flow

Montgomery Ischemic extremities in 45°C water are often painful there is insufficient circulation to carry the heat away There is some danger of burn

Hildes Although I would certainly like to agree with Dr Rodahl that local acclimatization is probably more important than metabolic acclimatization there are some systemic effects too which may of course be dependent on the local acclimatization such as changes in blood volume which may be called acclimatization

Rodahl How much is a result of exercise rather than acclimatization to cold? One is often measuring a combination of cold exposure and exposure to high levels of exercise There may be changes in blood volume resulting from exercise

Hildes We have some data (58) on medical students who are sedentary all year round these have an increase in their blood volume in the summertime as compared to the wintertime

Rodahl Could this be a seasonal change, regardless of temperature?

Hildes It may be but it is probably a result of temperature change

Montgomery Blood volume increase in warm weather was discussed at the Fourth Conference on Shock and Circulatory Homeostasis and by Doupe *et al* (58) and Bazett (59) It even goes back to Joseph Barcroft (60)

Meehan One of the best reviews is that by Sjostrand (61), who pointed out that, according to his own data, blood volume actually increased in the wintertime and went down in summertime This is true, but it is not separated from the exercise effect, which can be much greater The effect of exercise on blood volume can be quite considerable and can be produced rather rapidly

Burch How accurately do you think blood volume was measured?

Meehan It depends on the method

Burch Let us say chrome 51 red

Meehan I suspect you are probably good within 2 per cent of it, ±5 per cent of the true blood volume

Hildes von Porat (62) reckoned it to be within 5 per cent by his Evans blue method, as plasma volume

Meehan If you make enough measurements, you can arrive at the statistical true value, even though the method is not statistically accurate I think enough work has been done to show that activity alone can cause considerable changes in the total blood volume of an individual I have done some work on this, myself

Montgomery What order of magnitude?

Meehan Around a maximum of 12 to 13 per cent in my own experience

Ferrer Are these acute experiments?

Meehan No, the sort of thing where you may put a subject on bed rest for a while, then have him get up and become active The plasma volume changes first, with the erythrocyte volume following along The erythrocyte change requires around 30 days for a maximum effect Plasma volume itself, in my own experience, will change at around 1 week, or perhaps 5 days to 1 week, or at least start to show a change

Kark For what?

Meehan Depending on whether or not the subject is in bed, it tends drop If the subject is put to bed, the plasma volume drops There an increase in the hematocrit After a week, the hematocrit tends to djust to normal If the individual becomes active, there is an increase the plasma volume It seems to take about a month to achieve the rresponding increase in the cell volume

Montgomery It is agreed that blood volume increases when an

individual moves from a temperate to a tropical climate Hemoglobin falls relatively and then recovers I should like to hear about what happens to blood volume and hemoglobin when an individual moves from a temperate climate to the arctic I would expect little change, and if any, a change in the opposite direction

Meehan Blood volume is something that can be adjusted by the body to meet its own requirements That is why these changes occur The very interesting work of Dr J P Henry (63) at Wright Field would lead one to suggest that the body does have mechanism for regulating its own blood volume In exercise, there is an apparent need for an in creased blood volume because of the increased vascularity in muscle tissue It is well known that increased vascularity in muscle does occur when that muscle becomes active

Montgomery Climatic changes may produce great changes in cutane ous vascular volume but I know of no measurements that prove this

Meehan Particularly, I suspect the effect might be greatest in relation to heat rather than in relation to cold

Carlson The change, when you go from warm to cold is decreased blood volume, the change with exercise is an increased blood volume Isn't that correct?

Meehan You will find for both ways If you read Sjostrand, you will find an increase in the cold

Hildes That is against all the other evidence on that point

Carlson This is why I wanted to straighten it out I am sure you said the initial was a decrease

Meehan Bazett (64), who first reported this, followed the blood volumes of people in the cold room for a relatively short period of time His comment is that there is first a decrease in blood volume but after a few days it tends to return to normal A later paper is that of Conley and Nickerson (65), who followed people for a longer period of time than Bazett did They reported the blood volume did, in fact, return to normal

Tremont Smith But they promptly got increases

Horvath There are enough reports that say there is no change On the basis of over all evidence, the changes that occur appear to be insig nificant, and from the over all picture there is no change in blood volume

Hildes That isn t true in Winnipeg There is a significant change in a large number of individuals

Kark With I^{131} albumin technique?

Hildes Evans blue

Behnke Does that change the total hemoglobin?

Hildes From measurements of hemoglobin concentration and hematocrit, the total hemoglobin and erythrocyte mass seem to fluctuate seasonally parallel to the plasma volume

Behnke Did these medical students show evidence of acclimatization to cold?

Hildes These particular students weren t tested in any other way aside from their regular blood examination

Horvath Examinations occur in relationship to this?

Meehan How is the blood volume change expressed, body weight, surface area or absolute?

Hildes No regular change occurred in body weight over the period There were some ups and downs in some of the subjects but, over all,

comment In every
e comes up, we get
into exactly this situation There are data on both sides of the question, and data that show the other data were probably not significant

Burton These experiments were done in Winnipeg by Doupe and Ferguson (58) Dr Hildes was associated with them The experiments are very thorough indeed They have trained subjects that they have followed measuring blood volumes for more than 3 years, and at rather frequent intervals Is that not true? They show a remarkable cyclic change, from the data I have seen

Hildes They were studied at monthly intervals Most of them were done over a 12 month period and a few were done at longer intervals but over a 2 year period

Rodahl Is it possible that there was a difference in activity between winter and summer in your students? If they had more activity and more physical conditioning in the summer, this would tend to raise the blood volume I wasn t actually saying anything about the relationship between cold exposure and blood volume

Meehan I think this is one of the big difficulties in measurements of this type A good effort to regulate the activity of the individual must be made

Burch It is first necessary to decide upon the accuracy of the method That has been established Certainly, the routine hematocrit is not ccurate Blood drawn from the antecubital vein does not represent hat for the whole body

Horvath If you run the regular one to five hour curve, several of hose it is shown repeatedly that there is a difference

Fremont Smith Dr Hildes, did your subjects have known differences n activity?

Hildes During the school year they were ordinary medical students attending lectures During the summer many did relatively similar sedentary jobs some were summer students in the laboratory others had similar jobs a few were sleeping car porters

Behnke Many carefully conducted experiments by the Climatic Research Laboratory on one of the extracellular spaces is of interest in this connection It showed no change as I understand in the individuals that were cold acclimatized and those who were not Do you recall specifically the tests that were run?

Meehan At the Quartermaster Laboratory?

Behnke There was no change in the extracellular space

Meehan Those people didn t feel there was any change in blood volume

Behnke That is what I am saying

Hildes On the point raised by Dr Rodahl whether this was climatic or seasonal this change happened definitely in 2 out of 3 years I think it happened in 3 out of 3 years but it was less marked in 1 year than in the others This suggests to me that it is not seasonal but may be associated with climate There was no strict relationship with ambient temperature But the fact that it was irregular—and it was quite irregular from subject to subject some subjects achieving their maximum say a month ahead of other subjects—seems to me to indicate it is not a

winter

They were taking the group as a whole quite significant

Ferrer Was that only a group of male or were there some female students?

Hildes These were all male students

Rodahl I didn t mean to say that there was no use studying the general changes but I felt from a practical viewpoint that we would probably be more interested in how we can protect and use our hands and protect our face during cold exposure rather than devote all our efforts to studies within these rather fussy general areas where the variables are extremely difficult to control I didn t mean to say that we should forget all about the general acclimatization

Hildes These are probably related The blood volume changes may be associated with local changes in the vessels of the periphery which may then lead to the systemic changes

Rodahl Yes

Fremont Smith I was very much interested in one point going back to putting the arm into hot or cold water If the arm is put into cold

water, the body is up against two different situations which are sort of contradictory It wants to warm the arm to keep it from getting too cold, and so it appears that it dilates the blood vessels in the arm On the other hand, it might like to diminish the blood flow through the arm so as not to chill the body so much, and this might be more what would take place When you put one arm in cold water, there will be opposite vasoconstriction in the other arm, and heat will be retained there The reverse dilemma would be faced by the subject by putting the arm into hot water, because then he heats the body, if he dilates the blood vessels in the arm, and if he doesn't dilate the blood vessels in the arm, then that arm gets overheated too soon But he can, under those circumstances, dilate the other arm, as we know he does, and radiate a lot of heat out that way, and can afford to dilate the arm in the hot water Supposing you put him in a hot bath, then he is going to be heated on all sides What will he do then?

Montgomery He will become hyperthermic

Blair The whole thing is further complicated by the pain response to very hot or very cold water The pain response may override all other factors

Fremont Smith Particularly if the rate of change in getting him hot is fast You can get a person to much higher temperature without pain, if your rate of change is slow Am I not right?

Blair Yes, that is correct

Hildes Perhaps the English Channel swimmers are like Dr Irving's seals and have some sort of general insulating mechanism that is different from the rest of us who wear clothes

Blair Those who swim well in the English Channel certainly have a characteristic build Those that tolerate best the cold water of the Channel are the very large, heavy set, stocky type rather than the tall, lean, athletic type That is quite true in all cases

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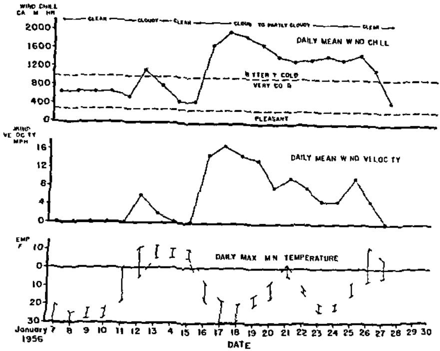

FIGURE 64 Weather data taken in the vicinity of the campsite

study were airmen stationed on this Base They are more apt to be heat acclimatized than cold acclimatized under ordinary conditions because of the overheated buildings here They were clerical workers who were unaccustomed to being outdoors more than an hour a day during the winter months They had been in Alaska a year, and an equal number

tle idea of the cold expo
as pointed out is true for
old stress imposed upon
man under these conditions is one of the most difficult things to evaluate

of the sleeping hours and from this we were able to construct a ... thermal balance sheet During waking hours we had to rely on scheduled activity, in the open with specified intervals for meals during which they could seek shelter

The men were permitted no heat during the time they were in the field with the following exceptions They built a small windbreak in

which they installed a wood-burning Yukon stove and in which they spent three half-hour periods daily, in order to consume their meals The mean temperature of this shelter for the period of the bivouac was 0°F (S D = 8°F) In addition, we had a heated observation shelter in the center of the campsite where we kept recording instruments The men would enter this shelter on occasional mornings, immediately after awakening, to be weighed or have thermocouples attached, however, they were never in the shelter for longer than 30 to 45 minutes

They were allowed to work out any way they could to ameliorate the weather conditions but had to meet certain minimal standards of activity, which I shall describe presently They built snow shelters and supplemented them with spruce boughs and parachute cloth They were in these shelters nightly from 8 p m through 7 30 a m , that is, almost half of the total time in the field During most of this time they were in their sleeping bags either asleep or talking Shelter temperatures tended to be around 5° to 10°F warmer than ambient air temperatures during periods of extreme cold This is generally true of snow houses unless they are very well constructed, when the gradient is much greater Of course, one doesn't have such a high windchill factor within the shelter

The sched [illegible]

gathering for the cook stove, chopping ice, improving on shelters and general KP duty The subjects participated to an equal extent in these chores Our own data involved considerable road work on the part of the subjects, and each man rotated through the observation shelter where thermocouples and the gas meter could be properly applied on the average of once every 6 days

Some idea of the energy cost of such a bivouac may be gained from inspection of the weight changes of the men and their caloric consumption On 11 of the 24 field days, interspersed at random, we carefully weighed each item of food that the subjects ingested This was recorded and converted into calories by Dr Drury who conducted that part of the study himself The subjects were weighed nude on 11 mornings during the course of the experiment on platform scales sensitive to 5 grams Figure 65 summarizes the results of the caloric intake and body weight changes

In Figure 65 the subjects are designated alphabetically With the exception of subject A, who voluntarily restricted his diet, the subjects ate as they wished, there was no restriction on the intake of their food

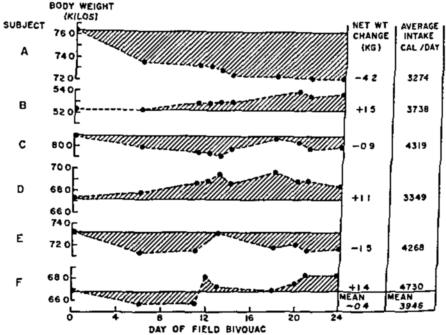

FIGURE 65 Weight chart and calculated mean daily caloric intake of each subject during the field bivouac Only subject A voluntarily limited his food intake

In the next to last column is given the net weight change in kilograms during the period that the men were in the field The mean net weight change was a reduction of 0 4 kg For reasons that I will explain shortly, I think that most or all of this represents a reduced body fluid volume The mean daily caloric intake for each man is summarized in the last column It ranged from 3274 calories per day in Subject A, who had restricted his diet and who lost 4 2 kg, to 4730 calories per day in subject F, who gained 1 4 kg The mean caloric intake of all six subjects during this period was 3946 calories per day This compares closely with the results reported by Welch (2) several years ago during a rigorous field exercise under subarctic conditions This caloric equilibrium does not represent a measure of the thermal stress on the subjects, rather it is a measure of the whole environmental stress, including the factor of cold Obviously, they could have achieved the same caloric intake and weight equilibrium in a temperate climate

In addition to this gross estimation of caloric equilibrium, we attempted to get the caloric cost of certain specific activities during camp life We were most successful in sampling the cost of skiing,

snowshoeing, and walking through level snow in the vicinity of the camp In order to accomplish this, an A-14 A oxygen mask was equipped with low resistance J valves and fitted snugly to the subject s face Heat production was estimated by measuring oxygen consumption using open-circuit indirect calorimetry Expired air was metered continuously

heated by four hand warmers placed about the outside of the meter A small flap in the pack permitted the meter temperature to be read by an observer at selected intervals The meter is equipped with a small diaphragm pump that diverts an aliquot of the total expired air volume to a small outlet We attached a heavy walled rubber tube to this out let leading to a rubber sampling bag (a punching bag bladder) which was kept inside the subject s shirt The composition of expired air in this bag remained constant over the period of time required before

energy consumption calculated from this and the volume of expired air This technique has permitted continuous sampling of expired air for periods up to one hour at environmental temperatures as low as —45°F

I have expressed the results in Table XVII as kilocalories per kilogram total body weight per mile per hour in order to reduce the vari ability resulting from differences in body size and pace Passmore (6)

TABLE XVII

Energy Cost of Locomotion in Vicinity of Winter Bivouac (kg cal/kg/hr/mph)*

Broken Trail Crusted Snow			Unbroken Trail Drifted Crusted Snow		
Walking	Snowshoeing	Skiing	Walking	Snowshoeing	Skiing
1 61±0 21†	1 58±0 18	1 71±0 21	4 04±0 53	2 48±0 17	2 48±0 40

*Corrected to exclude basal metabolism
†Standard deviation

has recently reviewed the effects of body mass and pace on en*
of locomotion, and a direct proportionality exists within the ra*
one to four miles per hour

To arrive at the final energy cost, it is necessary to add to thes
the basal metabolism It is difficult to compare these data with
other investigators because of unknown factors of snow textur*
ment design, skill on skis and snowshoes, etc. *Comparing our d*
those of Christensen and Hogberg (7) for skiing snowshoe*
walking through soft snow, there is surprisingly good agreeme*

figures may have some value in predicting caloric requirement*
ever, they are very incomplete

The estimation of thermal balance during sleeping and resting
shelters is an important field observation *Almost half of a man*
ity in the field may be spent in such a manner If it is not possibl
any data from him under such comparatively ideal conditions
tainly is not possible to get anything meaningful while he is st*
around in the snow We collected data on body temperatures, *m*
lism, and evaporative heat loss during nights spent in a snow
located near the observation shelter We considered this she
representative of the type of thing the men had constructed, a*
subjects felt that, in general, they had an average night's sleep
inside

... awakened the man several
athe into a Dougl*
le was analyzed a*
as it came *into temperature equilibrium* with our observation shac*
the caloric consumption was estimated as before

On all nights when we measured metabolism, we weighed the
jects before they entered their sleeping bags and immediately
arising the following morning before they voided This gave
measure of the total evaporative *weight loss from respiration and s*

Lastly, we taped fifteen thermocouples to the test subject's ski*
inserted a rectal thermocouple before he entered his shelter T
were connected to a portable potentiometer within the observ*

perature and rectal temperature 0 4 and 0 6, respectively, to ...
mean body temperature and assumed a body specific heat of 0 83

Table XVIII summarizes the results The mean metabolic rate under these conditions was 41 kg cal /hr /M^2 (standard deviation, 5 kg-cal /hr /M^2) This was not significantly different from the basal metabolism of these subjects, which was 43 kg cal /hr /M^2 when measured at the Base laboratory prior to and following the field bivouac The mean heat debt of the subjects was zero, that is they were in thermal equilibrium throughout the nights that these particular observations were made Some of the subjects actually had a warmer mean body temperature just before arising in the morning than upon entering their sleeping bag although our initial temperature observations were 2 hours after they had fallen asleep The coldest subject lost 3 5 kg cal /hr /M^2 over a 9 hour observation period

Hildes Did he shiver?

Rennie He did not complain of shivering and his metabolism was only slightly elevated above the mean That rate of heat loss represented a total heat debt of about 70 kg cal for that particular man His toe temperatures dropped from an initial level of 33 5° to 21°C during the night and he did complain of cold in his toes and feet Such a drop in toe temperature was an unusual occurrence under these conditions When we have observed it in this and other studies it has seemed to provide a reliable indication of a general body heat debt

Hildes Did he sleep right through? Was he happy?

Rennie He was reasonably comfortable I don t want to give the impression that this was always the case, even in this particular study

TABLE XVIII

Thermal Balance During Sleep While on Bivouac

Mean metabolic rate (21 observations)	41±5 kg-cal/hr/M^2
Mean body heat debt (7 observations)	0, range +2 5 to −3 5 kg cal/hr/M^2
Mean evaporative heat loss (26 observations)	14±3 kg cal/hr/M^2
Nonevaporative heat loss	27 kg-cal/hr/M^2

There were many nights when the men were uncomfortably cold in their own sleeping bags and shelters, we don t have any heat balance data on them under those conditions however

Blair What was the approximate insulation value of the clothing they wore?

Rennie These men had the double mummy arctic bag and they wore long woolen underwear, a woolen shirt, and two pairs of woolen socks The particular subject mentioned above wore his parka, apparently it didn t help him much The clo value for this ensemble is difficult to estimate For one thing, it is compressed on the ground, where conductive heat loss would be greatest, and the clo value there would be less than elsewhere

Blair The man wearing the parka didn t have any more clo value because he was in there tight?

Rennie I imagine that was the situation

Ferrer The title of Table XVIII states during sleep and yet this was while they were awake Is there reason to believe this is a proper assumption, the awakening has not altered their metabolic rate?

Rennie The metabolism was measured immediately upon being awakened at intervals throughout the night If it is in error, it should be somewhat high Awakening may have increased their metabolism

Burton That is a misunderstanding of the title You make the measurement of temperature when they awaken and before they start, but the result of subtracting what you got at the end from the beginning is what happened during sleep Isn t that right?

Rennie Yes but Dr Ferrer was worried about the metabolism data only

Ferrer That is right

Burch To obtain the evaporative heat loss you weighed the subject before he retired to bed?

Rennie Yes

Burch And again when he awakened in the morning?

Rennie Yes This is respiratory heat loss plus sweating

Burch That was about 90°F ?

Rennie Yes

Burch You used 0 58 calorie per gram of water vaporized for your calculations?

Rennie Yes that is correct All of this heat wouldn t be lost of course because some of it recondenses in the bag The mean evaporative heat loss was measured, and nonevaporative heat loss was calculated

Montgomery How would you measure the evaporative?

Rennie By measuring the change in body weight during the night Our scales were sensitive to 5 grams The only avenues of heat loss that these men had were evaporative and conductive There would be no convective heat loss inside a snow shelter and minimal radiation loss, even from the face, since the men slept with their heads drawn down inside the bag

Burton You did not weigh the bag to see how much of that exapora tive heat could have been recovered by condensation in the bag?

Rennie Yes We weighed the bags with this in mind, however we did not realize how high the temperature rises between the bag and the snow when we started this study We observed temperatures as high as +55°F among the spruce boughs beneath the bags at a time when air temperature in the shelter was −10°F Water enters the bag from melting snow and we were unable to correct for this In the future, I would use a plastic ground cover to prevent this

Rodahl This is a standard technique for measuring total evaporative heat loss It is the technique used by Adolph and his collaborators (8)

Carlson What was the average skin temperature in the bag?

Rennie It ranged between 32° and 33 5°C

Whaley Were they comfortable?

Rennie In the observation shelter, yes

Hildes You said the average shelter temperature was 5 or 7 degrees above ambient Does that apply to this shelter?

Rennie Yes, that applies to this shelter

Hildes Not the shelters they built themselves

Drury We had +23°F in our shelters

Rennie The shelters that were built on this bivouac were not the best snow shelters as we now know It is possible to heap up a great mound of snow, allow it to settle and then burrow into the ground and hollow out sleeping quarters Such a shelter is far superior to one made of snow blocks (which is the kind we constructed) and it is possible to have inside temperatures of +23°F when outer air temperature is −45° or −50°F without supplying any heat source This is the result

cooperative subject was a 24 hour measured oxygen consumption He wore the gas meter continuously during his waking hours and I measured his oxygen consumption during a variety of activities including wood chopping skiing sitting around in the cook shack, etc Sometimes, I would sample his oxygen consumption during a given activity, then remove the mask for the remainder of that particular level of work

When that was done, the time activity was noted and the total oxygen consumption calculated During the night, I awakened him four times to measure metabolism as I have previously described I can account for 97 per cent of the minutes of the day, and the total caloric consumption of this subject, on that day, was 3615 kg calories This is in rough agreement with the results of the dietary study and I think we can be fairly certain of the environmental stress on these men in terms of energy cost

Fremont Smith That is a rather remarkable performance

Rennie The physical measurements that we took on the subjects are summarized in Table XIX, which shows that the skinfold thickness did not change appreciably in these subjects I wanted to cite this prior to going into the cold room work because a marked change in skinfold thickness might have accounted for some of our results The body weight recorded in Table XIX is 0 1 kg higher following the bivouac than before, the discrepancy between this weight and that recorded in Figure 65 may be a result of rapid hydration on return from the field The men gained an average of 0 5 kg weight within the first 48 hours after returning from the field Unfortunately, we have no measure of fluid balance in these subjects

Hildes Have you some idea of their food intake and urinary output?

Rennie No, I do not

Kark Do you have any measurements of the physical fitness before and after they were in the field, and did you measure urinary ketones?

Rennie No, we have no objective measure of fitness of these men Naturally, they were more fit when they returned

TABLE XIX

Physical Measurements of Subjects Before and Following Winter Bivouac

	Age	Height (cm)	Weight (kg)	*Skinfold Thickness* (mm)		
				Abdomen	Chest	Arm
Before	25	175	69 5	5 7	3 9	5 1
Following	—	—	69 6	5 5	3 6	5 1

Kark I am interested in how fit they were before I am sure they were fit when they came out

Rennie From previous studies with airmen on this Base I would say they would have scored around 45 on the treadmill test in other words they were not very fit

Kark It is interesting that they haven t changed their body composition during training

would agree that the change was remarkable

Kark These are beautiful studies and they clearly indicate the amount of food required by troops to do the kind of work required under arctic conditions I wonder if Dr Rennie would care to say anything about water requirements for soldiers on the basis of his study or any other study he knows about Perhaps I could then make some comments on them

Rennie I am not prepared to give any quantitative data on water balance of these subjects nor am I familiar with any study of the water requirements of men under arctic conditions It is important that this study be done From my brief experience here I would consider that the problem of water supply to troops in a cold environment is paramount For instance during Operation Moosehorn the winter of 1955 1956 many of the units had some trouble with inadequate water supply and this was one of the most serious problems they encountered

Kark What do you mean by some trouble? Did they have dehydration syndrome?

Rennie I am not sure of their clinical condition I believe it was partly a problem in logistics The apathy that their squad leaders reported may very well have been part of the dehydration syndrome

Hock Also the men were apparently apathetic at the end of the day and d d not like to melt their own snow and ice to get water They were also in fact apathetic about preparing food The medical observers were worried about the fact that the men were being furnished with 4 000 calories a day or something like that but appeared to be eating only 1 200 They were also not getting much liquid These were fairly long exercises of several days to a few weeks in duration

Montgomery Wouldn t we feel thirsty on shift ng from water to snow regardless of what we are doing? Isn t there less of a satisfaction with its bland taste and uncomfortable sensation of cold to the mouth?

Rennie I think it is just related to the amount of water you can get from a mouthful of snow

Montgomery But does one choose to get his water that way or choose to be a little thirsty?

Hildes It seems that people aren t particularly thirsty This apparently was a very important aspect of the Everest expedition according to Pugh (9) Although the mountaineers didn t particularly complain yet he felt they could easily become dehydrated and had to go actively after water rather than just alleviate their thirst

Montgomery There are two reasons why that might be so Snow water doesn t have any salt in it to give taste and it is sometimes difficult to obtain

Blair A third factor may be that thirst is deadened by breathing very cold air into the mouth and the respiratory passages This is probably true because reports coming from Operation Moosehorn stated that soldiers were definitely becoming dehydrated although there were no complaints of thirst or desire for water

Horvath They drink water if they have water available

Rennie Often they have to be encouraged to drink water

Burton I don t know if we are thinking of dehydration as necessarily something deleterious It might be physiologic adjustment I wanted to say that I felt we made a mistake in getting involved in an argument about what happened to the blood volume because as far as I am concerned even with all the skillful work done on blood volume determinations we still don t know what it is when we get it For instance none of the blood volume studies obeys the elementary criterion one would ask of any method which is that recovery studies should be satisfactory Everybody knows if you add by transfusion 500 ml to the circulation in a subject you do not find by these methods that the blood volume has gone up by 500 ml Similarly if you bleed 300 ml you don t find 300 ml less in the blood volume

What I should like to concentrate on is the very clear evidence of a shift in water balance I don t think anybody who has looked for it has failed to find a very great diuresis lasting a day and a half when people are first exposed to cold

If you study as Bazett and I (10) did so many years ago the water they take in and the water they put out in the urine and calculate the insensible loss you find there is a very big shift indeed in the first few days of going into the cold conditions

I think more studies perhaps should be done on the water balance and we shouldn t put too much reliance on blood volume studies which would be very difficult to do in the field anyway

Rennie I feel that the rapid rise in weight on returning to the Base was presumptive evidence that the subjects were slightly dehydrated under the field conditions in spite of an adequate diet and water supply

Burton You don't feel dehydration necessarily is a bad thing in these?

Rennie No

Burton It might be physiologic adjustment?

Rennie Yes

Drury We have tried all sorts of different diets, mostly calorically restricted, and participated in field studies where I feel there may have been relative caloric restriction When a man or an organism is exposed to stress, suddenly increased needs for exercise, cold, or some situation which eventually calls for increased caloric intake, it takes several days for him to start eating more In fact, if men are taken out on, say, a 10 mile hike, they come back too exhausted to eat for a while Only 2 or 3 days later do they begin to increase their consumption During this early lag period there is caloric restriction When there is caloric restriction, either from reduced intake or from increased requirements, there is dehydration In our experience, in every case, it is self limited It is all over, if the subjects stay on the same regimen, in a matter of 3 or 4 days There is a loss, I would say, of 6 or 7 pounds, and that is it

Kark I am sure you are right, Dr Burton, we need more studies on water balance I don't think this is something that ought to be passed over rather lightly, especially from a military point of view I feel the most serious supply situation in survival in the cold and in active military operations is provision of enough water or means of preparing water Whenever there has been man failure in arctic military tests of rations, it hasn't been through hunger, but it has been through marked dehydration For example, trained soldiers, who had spent all their lives in northern Saskatchewan and who were all farm boys, became completely useless militarily at the end of 36 hours when water was not supplied and they had to eat snow

Drury We tried to fight the dehydration by forcing water and it didn't do anything as judged by weight loss Also, in the case of a very few subjects, of which I [illegible]
would hold the water
makes 250 ml of physio
point of nausea, practically, and it made no difference We still got this weight loss which indicates dehydration

Crismon Doesn't that mean there is natruresis as well as diuresis at this time?

Drury Naturally, whatever goes in has to come out

Crismon Wouldn t that be tied in with the absence of thirst that has been commented on?

Drury There is reduced thirst, even though you are dehydrated When you stand up suddenly, you get a vasomotor postural response indicating reduced blood volume and your lips are dry

Montgomery Is that sensation a clear indication of dehydration?

Drury Probably, but not necessarily There is increased hematocrit and cell count, every indication that the blood volume, which we have not actually measured, is decreased, a dry mouth, and rapid initial weight loss It all adds up to dehydration

Travell Did you take the salt tablets with water?

Drury They were taken with water

Travell Enough water?

Drury Yes

Fremont Smith Some years ago dilute salt solution was used, salt was added to the water to the same extent as the sweat This became very palatable It just occurred to me, if the salt were dissolved in the water in the same proportion as the loss of salt by sweat, you might have a water that would be drunk with satisfaction

Kark Did the salt tablets dissolve? It is a well known fact that most of them are pressed so hard they don t dissolve in the gut, all they do is give you colic, and pass right out the other end

Drury They didn t come right back out again I agree dehydration does occur, and I strongly agree with Dr Burton that it doesn t make any difference I don t feel it is a bad thing in itself I should like to add that, in a cold environment, very frequently, the thing that causes a person to drink is not thirst but a desire for something warm to drink Often you drink a cup of hot tea because you want some warmth and not because you happen to be thirsty You could get very thirsty, but I am talking about situations where people have all the water they want to drink

Irving Do the soldiers like water?

Drury Water, tea, coffee, no calories

Irving All of these available, warm drinks?

Drury Yes

Burch It depends upon whether or not the failure was becoming worse or better, but they may behave like the normal That question cannot be answered satisfactorily until we can determine the volume of the various water compartments adequately But how does a compartment increase or decrease to a certain level and go no further? Certainly, when one goes out in the cold, the physiologic state is changed, but how are the changes regulated?

Behnke I should like to emphasize the importance of what Dr Kark said about following the water balance Over the past year, in nutrition experiments, it was evident that one of the great oversights was failure to ascertain accurately not only water intake and urine output but mineral intake I am not sure about the cold diuresis at all I don t think we can speak of it until we know what the mineral intake is in the diet I think a profitable study on these individuals would be to measure total body water, using tritium About 5 liters of water can be lost and then one approaches a state of incapacitation Therefore, I should like to emphasize again the need to know the mineral intake In diets you were speaking of were the subjects eating meat bars?

Drury Yes also other things

Behnke They developed ketosis, which in our experience has been associated with a loss of 2 to 3 liters of fluid This is a dietary effect which can be avoided

Montgomery Can you pick up the 500 ml loss or gain that Dr Burton was talking about, with tritium?

Behnke Yes, it can be picked up

Montgomery So a more accurate method, according to you, than any blood volume measurement can be made?

Behnke Take a half dozen men and get the mean value The error there will be ± 200 ml

Montgomery Yes, I know We were talking a little while ago about blood volume Captain Behnke is talking about total body water, and I was asking whether you can pick up that much change in total body water, as Dr Burton suggested, 500 ml in or out, in this instance, by the tritium method Your answer was Yes

Behnke The 500 ml would be a bit close on one individual

Montgomery Are you sure your method is any better than the blood volume method?

Behnke Yes

Fremont Smith If you say better you should say better with respect to what

Montgomery More accurate, then

Fremont Smith They have different goals, the two methods

Montgomery Yes, water gained by the blood or outside the blood

Fremont Smith Water gained or lost Blood volume doesn t pretend to measure that

Montgomery No The argument was to abandon blood volume because it isn t a good method I asked Captain Behnke whether the method he has is more accurate, admittedly for a somewhat different purpose

Behnke There are so many variables affecting blood volume, but total body water is more stable Secondly, it is a larger entity It is of the order of 45 liters compared with 6 liters for blood In half a dozen individuals, using the mean value, it will be ±200 ml For any given individual it will be about the standard error of estimate, which is ±2 per cent This amounts to about 1 liter This is well within the range you are interested in because dehydration can be of the order of 3 to 5 liters

Burton This disparity between water intake and water output from the urine during these first few days in people exposed to cold, will amount sometimes to 2 liters So I think one could measure it Perhaps by using the word diuresis I misled people into believing this necessarily connotes dehydration Stein *et al* (11 12) looked into this very carefully It is a salt and water diuresis So that it doesn t necessarily mean that it would produce dehydration It means there is this fluid lost from the body

Fremont Smith Also we should specify what we mean by dehydration Some of us are using it as meaning a loss of fluid which is useful to the body and others of us are using it as a loss of fluid which is of benefit tor the body to get rid of Do we mean physiologic dehydration or pathologic dehydration?

loss of water, or loss of water beyond what the body should lose tor adequacy?

Kark Beyond what the body should lose for maintaining military efficiency or any kind of efficiency Those are two separate things

Drury What I meant by dehydration was pathologic dehydration That is harmful of course I mean loss of water is not necessarily beneficial but I don t believe it does any harm

Fremont Smith That is not dehydration in Dr Kark s terms at all

Drury I don t think we are contradicting each other

Montgomery I am interested in the sensation that accompanies dehydration This probably has some practical value as a warning What does it feel like?

Drury Figure 66 shows what we mean and what Dr Kark means by dehydration because it is from his own paper

Kark It shows a mixture of dehydration and fatigue That is not just dehydration

Drury Dehydration is a large part of it

Kark There is ketosis producing involuntary dehydration

FIGURE 66 Condition of troops on third day of pemmican ration study Reprinted by permission from Kark R M Johnson R E and Lewis J S Defects of pemmican as an emergency ration for infantry troops *War Med* 7, 345 (1945)

Drury Did those people have water ad lib?

Kark Those soldiers had as much water as they wanted They were supplied with hot tea Because of their ketosis they had involuntary dehydration

Rodahl Produce 3 or 4 pounds of water in half an hour and you feel wonderful

Fremont Smith That won t be dehydration from Dr Kark s point of view yet there would be a lot of water lost

Burton Dr Kark and others are interpreting dehydration as meaning an increase in the osmotic pressure of the body fluids, whereas the word itself connotes just loss of water I want to make clear that I don t think this cold diuresis necessarily led to dehydration by the physiologist s definition because salt is lost also It is a salt diuresis I think the physiologist by dehydration means a loss of water without a corresponding loss of electrolytes so that there will be an increase of osmotic pressure

Fremont Smith Would freezing point be helpful?

Kark Those have been done by Johnson and Sargent (13,14 15) who

made studies of various types of rations, measuring osmolar loads and osmotic pressure, osmolality of the serum and urine

Fremont-Smith In cold?

Kark Yes

Fremont Smith This is crucial to our point What did they get?

Kark They have a tremendous amount of data on Air Force troops they were studying

Fremont Smith Do we know what they got from cold alone?

Kark In terms of what?

Fremont Smith In terms of this very point Was the freezing point depression lowered?

Kark Yes When troops were on a meat bar, for example, there was marked loss of water, over and above salt So that there were definite changes and deterioration

Fremont Smith That is a dietary situation, that isn't cold

Kark Yes

Fremont Smith Could they give us data on the effect of cold, which is the issue we are talking about?

Kark I can t remember I am sure they have it available

Burton If I may coin a word,—I am confident that they suffer a defluidation I am not sure whether they get a dehydration

Behnke Dr Drury conducted a test with the meat bar ration, in which he showed there was ketosis and loss of water Our results were similar in that there was a loss of 3 liters of water, for example, in an individual over a period of a week on a meat bar ration (1,000 calories) This loss of water was due to the ketosis

Drury Why do you say that it was due to ketosis?

Behnke It was associated with the ketosis, because the salt intake was approximately that in the meat bar, 2 gm, which is low

Drury It was associated with it, but how do you know it was the cause?

Behnke It wasn t a mineral diuresis

Drury How do you know?

Behnke Because when the subject went on another type of diet, with higher salt intake, he gained it back

Rodahl If the experiment is carried on the ketosis diminishes

Behnke This is what I heard

Rodahl It was shown by DuBois* when his group studied Stefánsson and Anderson on the meat diet After a whole year on the meat diet they found there was a marked reduction in ketosis I think this is well

*DuBois E F Personal communication 1951

known If you do go on the meat bar diet for one week and come bac and do it again, you do acquire this adjustment

Drury Figure 67 shows urine acetone (in the third curve from the top) These data are not based on spot tests but on total, quantitative acetone, aceto acetic acid and β hydroxybutyric acid For the first 3 days the subjects were on a normal diet The rest were on 1000 calories per day The acetone began to rise on the fifth day (about the second day of the experimental diet) The spot test would be extremely positive at the peak but the maximum excretion was only 2 4 gm for 24 hours on that day After reaching the peak, the excretion fell off, even though this low caloric intake was maintained for 30 days

Hildes You introduced some carbohydrate

Drury That is right, but it was not the carbohydrate that did it, as we found out Unfortunately I don t have an illustration to show Anyway, it came down We have repeated this many times A peak always occurs in a matter of days As a matter of fact, the third or fourth day is usually the highest one

Kark What was the range of activity?

Drury That was sedentary We find the same thing in rather severe

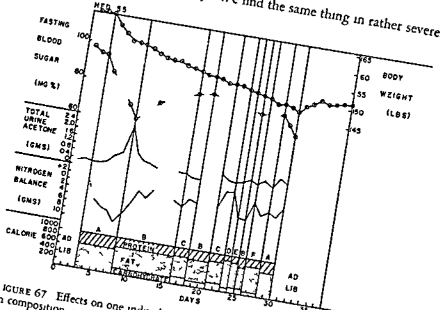

FIGURE 67 Effects on one individual of a series of experimental rations varying in composition as shown but all supplying 1000 calories per day

exercise, too, however Let s look at the top curve for a minute This is the body weight curve Notice that it falls off very sharply at the beginning of the dietary restriction By about the third day of restriction, the rate of decrease has slackened off to a steady half pound per day This is just about what one would expect on a 1000 calorie intake At the end of the restriction, on the 30th day, there is an abrupt gain in weight which then levels off in 3 or 4 days I believe that this gain represents the restoration of water lost at the beginning Incidentally, it is accompanied by thirst

This behavior is not restricted to the meat bar diet I suppose there are millions of private experiments performed every year in the United States with a variety of reducing diets It is practically universally found that almost any diet works beautifully for a few days I believe this is due to dehydration Then the weight loss slows down and people get very discouraged Often it goes stepwise too At the end, when a person gives up in disgust, a large part of the weight comes rushing back again This is a matter of water balance I don t know what the explanation is Whenever you restrict calories, you seem to have dehydration Perhaps defluidation is a better word if dehydration has come to refer to a pathologic situation

Fremont Smith You don t have this for cold?

Drury I don t have an illustration for cold The same thing happens, though but in exaggerated form because there is a higher caloric expenditure This is not, however, due to the cold as such

Fremont Smith But with adequate caloric intake?

Drury No I am sorry This is malnutrition only

Fremont Smith So that the point is, this particular kind of experiment is quite crucial to our discussion We don t have straightforward cold experiments as yet Is that fair to say?

Drury I am afraid we haven t separated the effects of cold and caloric restriction, because I think that in the experiment that Dr Rennie is describing there is the possibility that in the first few days they were relatively calorically restricted This is just an idea Maybe there is nothing to it

Burch How do you explain the ketosis?

Drury The important thing is to explain why the ketosis stops I don t know the answer High fat, whether the fat comes from your own body or from your food and low carbohydrate—

Behnke The negative nitrogen balance may be an explanation for water loss That is, one is losing body protein and with loss of protein also a certain amount of water that accompanies it

Rennie The question which remains is what effect did this field ex

posure have on the cold tolerance of these subjects and on their physio logic response to cold stress? The parameters that we measured in attempting to answer this were body temperatures metabolism and shivering during exposure of the nude subject to an ambient air temper ature of 50°F for 100 minutes

The men reported for the test in the fasting state and rested for 45 minutes clad only in cotton shorts and in a room maintained at 31° to 33°C They were then brought into a room at 20°C and covered with a quilt except for the exposure necessary to tape on thermocouples Finally they were wheeled into a cold room on a wheel stretcher still covered with the quilt and rested for an additional 30 to 45 minutes in the cold room while control measurements of temperature and metabo lism were completed The quilt was then removed so that they were suddenly exposed and they remained so for 100 minutes During the time of cold exposure temperature measurements were recorded on two recording potentiometers Expired air was metered continuously and an aliquot of 150 ml /min was passed through a Pauling oxygen analyzer The oxygen tension of expired air was recorded each minute and averaged for each 5 minute interval The volume of expired air during that same interval was recorded and the oxygen consumption and heat production were calculated from these data (5)

Figure 68 summarizes the results of body temperature measurements In plotting the results I have used average values Each point repre sents the mean of duplicate observations on all six subjects or twelve observations in all The statistical analysis was done by using an analysis of variance entering a table of F and estimating the P value from this There was no change in the course of rectal temperature in these sub jects as a result of the field exposure After the bivouac the skin tem peratures ta
before I d
may As f
increase of about 6 kg cal /M² which should not be very important

The average skin temperature was calculated according to the formula of Hardy and DuBois (16) using sixteen skin thermocouple sites The decline in average skin temperature was at a lower rate for the sub jects following the bivouac The skin temperature following the bivouac remained significantly higher than the pre bivouac values throughout the first 80 minutes of the test The mean values beyond

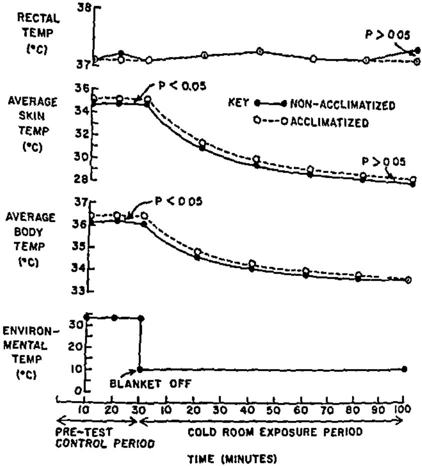

FIGURE 68 Mean rectal average skin and average body temperature during the control period and cold exposure of all cold tests Each point is the mean of twelve observations on six subjects Body cooling was almost identical during each series of tests

heat debt amounted to 81 kg cal /M² during the pre bivouac tests and 86 kg cal /M² during the post bivouac tests

Burch What about shivering?

Rennie I will come to that in just a moment As far as regional skin temperatures were concerned there was a significant difference in the cooling pattern of different regions of the body Figure 69 summarizes representative data on regional skin temperature Trunk temperature the skin of the face and that of the upper part of the legs cooled to the same degree in the men before and after the bivouac

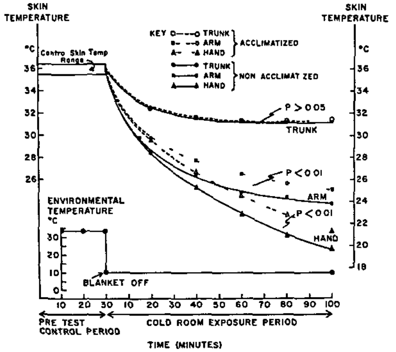

FIGURE 69 Mean skin temperature of the trunk arm and hand areas during the control and cold exposure periods Each point is the mean of twelve observations on the six subjects Cooling of the trunk region is identical before and following the field bivouac Arm and hand temperatures of the acclimatized subjects are significantly warmer than when nonacclimatized

The distal extremities the arms hands feet lower leg and digits did not cool as much following the field exposure The relatively small contribution of these skin areas to the average skin temperature accounts for the failure to detect any significant change in average skin temperature after 80 minutes exposure

EDITOR'S NOTE The following has been added by Dr Rennie in place of his original discussion at the Conference

The increase in the mean metabolic rate of the subjects during the cold tests is illustrated in Figure 70 It is apparent that no change occurred in the metabolic response of these men following the field trip

Since the heat debt and the metabolic rates were almost identical at the completion of each series of tests the total body heat loss sustained

found for still air alone and probably is due to the fact that the men were lying on a blanket covered stretcher that prevented the circulation of air over the posterior skin area

I have indicated in Table XX the regional skin temperatures and the corresponding thermal circulation indexes for the average subject at the completion of the cold tests It is clear from this that the distal extremities of the acclimatized men were warmer and that this was most likely because of an augmented blood flow to these regions These

TABLE XX

Regional Skin Temperatures and Thermal Circulation Indexes at the Completion of the Cold Tests

Skin Area	Skin Temperature (°C)		Thermal Circulation Index	
	Pre Bivouac	Post Bivouac	Pre Bivouac	Post Bivouac
Trunk	31 2	31 4	3 48	3 64
	(P>0 05)			
Head	29 4	28 8	2 46	2 50
	(P>0 05)			
Thigh	26 4	26 3	1 50	1 48
	(P>0 05)			
Calf	24 0	24 5	1 05	1 13
	(P=0 05)			
Foot	20 1	21 3	0 60	0 71
	(P<0 05)			
Arm	23 7	25 0	1 00	1 21
	(P<0 01)			
Hand	19 6	21 3	0 55	0 73
	(P<0 01)			
Fingers	13 6	15 2	0 15	0 23
	(P=0 05)			

observat
cerning
acclimat
additional heat that must be supplied to the skin mass of the distal extremities in the acclimatized men It did not come from increased metabolism as indicated by Figure 70 Rectal temperatures were not significantly lower in the acclimatized men at the end of 100 minutes exposure although it is evident from Figure 68 that a trend in that direction was developing By exclusion, we accept Dr Carlson s concept of a diminished core shell ratio in these acclimatized men Cooling of subcutaneous tissue and possibly skeletal muscle tissue to a greater degree in the acclimatized men would account for the results, in other words the body shell sustains a greater heat debt than would be the case in nonacclimatized men without eliciting a greater than usual rise in metabolism During more prolonged chilling we can only speculate what this would mean to the acclimatized man Obviously, the capacity of the body shell to sustain a heat debt is limited The cooling may extend to far deeper tissues than those we ordinarily consider shell tissue perhaps even a fall in rectal temperature may occur in acclimatized men earlier than in nonacclimatized men Dr LeBlanc s recent experiment (19) indicates that this may be so Eventually, heat flow to the skin of distal extremities from deeper tissue must decrease and extremity temperatures must fall Heat from metabolic sources must become of increasing importance during extended chilling and the ability to elevate metabolism for prolonged periods must be a vital feature of cold acclimatization under these circumstances unless the entire body temperature level falls in acclimatized men Our data are not extensive enough to answer these questions We can say that early in cold stress heat is supplied to the skin of distal extremities in greater quantity in acclimatized men than in nonacclimatized men and that the source of this heat must come from body tissue cooling because metabolism under these conditions does not differ from that of non

many times you made this series of the same subject?

Rennie Four times

Travell On the same subject?

Rennie Yes In other words, a total of twenty four individual runs

Travell Was there any difference with the passage of time?

Rennie No

Travell On the same subject?

Rennie No

Travell They were always the same?

Rennie That is correct for the two pre bivouac tests and the two post bivouac tests When you compare the post bivouac runs with the pre bivouac runs there is a significant difference

Travell But you took the same man and made this series of observations on him?

Rennie That is right

Travell So many days later you made it again? You didn t study the effect on skin temperature of exposing the skin all over the body in the nude state to cold These were areas of the body that are ordinarily covered?

Rennie In this study we did not determine the effect of cold room exposure *per se* We have done that on other occasions and have found no effect from this degree of exposure

Travell If you exposed the bodies nude in the cold room then you didn t determine what effect that exposure had on the subsequent variability of skin temperature

Fremont Smith Dr Travell means if you had continued say after they came back from the bivouac for 4 or 5 days in succession with the same individual She is asking about acclimatization in the cold room not recovery period

Carlson This is LeBlanc s (19) experiment

Burch I should like to tell of a few experiments we have performed which were similar to those of Dr Rennie except that instead of simply uncovering the individual we removed him from one room to another room that had already been adjusted to 12°C I was interested in the effect of cooling on pressure in the veins of the surface of the body This is of interest not only in normal man but also in patients with congestive heart failure in whom venous pressure is already elevated We know what happens in congestive heart failure if venous pressure is raised Therapeutically it is advisable to lower the venous pressure We know that change in venous pressure can initiate cardiovascular reflexes in normal persons as well as those with high venous tone We placed thirty medical students in a comfortable room and measured the pressure in their median basilic vein and also noted the hepatojugular reflux test The response was normal We moved the subjects into the 12°C room and let them lie there until they were about to shiver Just before shivering appeared we found a rather extreme rise in venous pressure in the median basilic vein The hepatojugular reflux response became abnormal

When we placed patients with congestive heart failure who had an elevated venous pressure signs of failure and an abnormal hepato

jugular reflux response in the same cool environment, the venous pressure did not change in every instance Four of them, however, went into acute cardiac asthma, with rather acute pulmonary edema

The hepatojugular reflux test became so abnormal in one patient, I think I could have killed the patient if I had pressed on the liver hard enough This patient had to be handled very gently I do not understand the entire response to the cooling but I have ideas about it The response reminded me of what happens to a patient with a tight mitral valve who walks out into the water at the beach As you know, when such a patient walks into deeper and deeper water, he becomes more and more dyspneic, and has to walk out onto the beach again I think the water squeezes the superficial veins and displaces blood into his respiratory tract to overfill it This may be the type of mechanism by which body cooling causes dyspnea in the patient with congestive heart failure We plan to measure the work of the heart and measure the pressure-volume diagrams of its chambers to learn what happens to the manifested work of the heart, as we did for a hot and humid environment (20)

Carlson Why do you think of squeezing the veins instead of just vasoconstriction?

Burch Walking into the cool water may produce both The cool room produced venoconstriction

Crismon You meant outside pressure rather than muscular

Burch The pressure of the water upon the body

Carlson In the failing heart, I should think vasoconstriction of a flushed skin would be a rather heavy load in the lung

Burch The cool room produced venoconstriction In fact, you know this occurred by gross inspection of the veins The venipuncture in the cool room is more difficult, in fact, I have difficulty finding the vein at times The veins are contracted and more difficult to puncture, resembling a small artery The point I wish to make is that, in the study of the response to cold, we always think of the normal man, but the abnormal man is another individual that deserves consideration One wonders how many people develop cardiovascular difficulty when they acutely enter the cold We know patients with heart disease in cold areas of the world will live long provided they live in 'tropical conditions which their homes and clothing provide If they should become exposed to cold and become chilled, cardiac asthma might possibly develop

Carlson Dr Horvath has published data on this point (21) It is erroneous to think that when I put on my coat and walk into the cold that I am in a tropical environment Dr Horvath demonstrated how rapidly the skin temperature drops in clothed individuals While the

clo is defined as keeping the skin temperature at 33°C, the actual fact is that when we go out in the cold, skin temperature drops The pattern of skin temperature change in Dr Horvath s experiments is similar to ours (22) with subjects in shorts at 10°C

Burch I am not thinking of −40°C Most people in America do not live at that level

Carlson Most people don t wear 4 clo either

Burch An ordinary man dressed to go outdoors is warmly clad I do not know whether or not his skin temperature declines and to what degree

Carlson It may be that the person exposed to cold receives cues from exposed parts such as face and hands

Burch I think it is a matter of how well he is dressed and the level of the environmental temperature that will determine what will happen to the skin temperature Obviously, if he is chilled, his temperature will decline If he isn t chilled, it should not change very much It is purely simple thermal physics

Horvath It depends on whether he is active or inactive

Burch Surely, whether or not he drives in a heated automobile, and then steps directly into his office, or whether or not he walks to work, are factors involved, there are many factors which must be properly defined to understand the nature of the physiologic changes to be expected

Burton I think I would disagree a little with Dr Carlson I think the important factor governing the reflex vasoconstriction, when an individual is clothed and exposed to cold, is much more the amount of exposure on the face, the one part that is exposed, than the skin temperature over the receptors over the rest of the body

Carlson I am arguing the average skin temperature drops The cue may be from the face, but the average skin temperature does drop

Burton I remember, early in the war making measurements on forty or fifty people sitting in heavy flying clothing in a cold chamber (23) I was impressed by the fact that though their average skin temperature dropped, it didn t drop nearly as much if they were naked in a room at 60°F As a result, there was no vasoconstriction or shivering until after a couple of hours, by which time their core temperature had dropped quite a bit In contrast, when I tried the experiments at about 10°, at 0°, and below 0°F, particularly with wind on the face, I could never get their rectal temperature down at all Just that extra amount of stimulation of the fact brought on the whole defense mechanism So I do feel that a heavily clothed man going out in the cold has his reflex mechanism greatly inhibited

Horvath I think you had the faces protected from the wind If you

leave the faces unprotected, the temperature drops a lot faster That, I believe, has been documented a number of times I am sure there must have been protection The facial reflex does not actually play as important a part as we like to think Certainly, this is an interesting fact A fine anginal attack can be induced in the patient by placing an ice cube in his hand or putting one on his forearm or chest I don t remember that it was *ever done on the face* I know these other sites are just as important

Burch I am not *saying they are not just as important, but the circum*stance of heavy winter clothing on portions of the body must be considered If the skin temperature of the body is measured, it probably *does not decline very much*, whereas *skin temperature of the face of the* same individual will decline enormously when he is exposed to the cold

EDITOR S NOTE Dr Travell would like to add the following after thought to her remarks at the conference

> *It is paradoxical that a patient with pain of angina or acute myo*cardial infarction can be relieved of the pain within a few seconds by application of ethyl chloride spray to the chest We showed this too

> ferent type of reflex must be initiated

Crismon I am impressed by the comment made by Dr Burch because it focuses attention on the loose terminology You speak of vasoconstriction in the cold Actually, that term should be applied to the arterioles From the point of view of hemodynamics, it is a factor of resistance added The important aspect Dr Burch brought out was the emptying of the venous reservoir of the skin After all, skin is about 18 per cent of the body weight, and it contains a good deal of blood By the time that is diverted into already engorged venous reservoir, *this* additional component makes a good deal of difference, but it is not detectable in the ordinary individual whose internal capacitors can *increase their volume to accommodate it without any increase* in pressure, usually

Fremont Smith What term would you use, venoconstriction ?

Crismon Yes Hemodynamically, they are quite different and the mechanism might be quite different

Burch Returning to the temperature effects Dr Carlson mentioned I agree with what he said, that temperature can change *if the situation* is proper for it, and it will not if the situation is not proper But the vasoconstriction reflexes vasoconstriction from chilling can produce fairly rapid and extreme constriction in a part *before* there is any

appreciable change in the temperature of the part If thermocouples are put on fingertips and another hand dropped into cold water veno constriction and arterial constriction will be noted rheoplethysmo graphically before the temperature is noted to change thermometrically

Horvath Your temperatures must have dropped You said you car r ed them to the point where they were about to shiver

Burch I am discussing the situation for a chilled man We have experiments of another sort *i e* where a man is covered adequately and comfortably When his hand is put in cold water and the digital vascular changes measured rheoplethysmographically a quick change is noted which is independent of any measurable body cooling

I think some of the venoconstriction that we encounter is not necessar ily due to total body cooling of the clothed man in this experiment

Carlson You are reinforcing my earlier point

Burch We too frequently pay attention only to the normal individual who can cope with these types of exposure It is rather difficult if you want to speak loosely to kill a normal man but when you have a person whose physiologic state is just balanced between remaining alive and dying it is fluctuating a great deal In normal man almost if not all biologic phenomena including biochemical fluctuate within a narrow ra Just a

h the periphery may cause deleterious changes?

Burch I don t know the mechanism of it I think part of it is due to the lobal filling of the lungs

Carlson It seems reasonable

Behnke I would like to call attention to roentgenologic studies in England in which in cooled individuals shift of blood from the periph ery to the core was shown by enlargement of the liver the heart and internal organs It is a very interesting demonstration of what happens

You speak of the periphery and the core Where does the core begin and how much of a shift in blood does it amount to? Who has meas ured it?

Burch Dr Rennie has used the term

Rennie Although the terms core and shell create a rather simple mental image as a basis for discussion I do not think we can be too precise n defin

gation

across

Beh

at 20°C The skin temperature trunk temperature is 20°C The deep

body temperature is 38°C How deeply does one go into the body to reach a temperature of, say, 36°C ?

Rennie That would depend on where you chose to enter the body Over the liver, the depth would be small compared with what it would be in the calf or arm

Behnke I was thinking of Dr Irving s earlier presentation I think he has come close to the kind of answer that would be helpful to me

Irving With animals, yes

Burton Dr Bazett and McGlone (25), as far back as 1927, did this in the human, on themselves, for the thigh and the leg and the arm They give these gradients, but not in very cold circumstances As I remember, before the temperature became constant, they were as far as 1½ to 2 inches deep

Montgomery I have never used the term core' Were you implying that core is deep in the extremities as well as in the trunk?

Rennie Yes I would consider that as part of the core, particularly the proximal deep portion of the extremities It may extend out into the proximal portion of the deep part of the extremity, it may be very high in temperature

Montgomery It could be defined as those parts of the body having a temperature close to the highest temperature within the body Its volume would vary with environment, with environmental temperature, and with regional metabolisms and regional and central circulations

Carlson I am afraid we can t clarify it very much because we know there is no fixed temperature within the body

Fremont Smith Are we clarifying something which is not an entity? Isn t it really a mistake to use this term in any sharp context, because it is obviously going to vary? If the whole body is in warm water, the whole body becomes the core This shows the extreme of the situation It seems to me it is much better not to use a term like that, which will tend to become identified with the particular area of the body, when, actually, we know the area of the body involved will vary with varying conditions

Behnke How does Dr Burton compute total body heat from his equation? Isn t the calculation, certainly, based on the idea of a core and periphery?

Burton Just because we have to make reservations about the core and the shell altering their ratio in different physiologic circumstances, that does not mean that it is not useful to employ these terms I have been very grateful to Dr Carlson for supplying short, simple words in these concepts I find it very helpful to talk about the core and the shell As one knows more about it, one has to make reservations These are

not fixed elements What is, in physiology? We were talking earlier about the blood volume What is blood volume? The factor that is measured isn t a geometrical factor, it is the circulating blood volume, if you like That is strictly analogous

Montgomery What is the core except, then, the part of the body that has, within narrow ranges, the top temperature?

Burton Yes, where the temperature is fairly homogeneous

Behnke For a stable condition of 20°C, for skin and water temperature, how deeply does one go into the muscle layer to reach a temperature of 36°C?

Crismon If you are willing to select an instant in time, you might be able to find the point where the transition was detectable, but an instant later that might have shifted a bit back and forth

Burton Moreover, Dr Bazett (26), in his later experiments, investigated the gradient You find plenty of circumstances where the gradient even reverses, as you go deeper in the tissue You would have to say that as your needle hit part of the core, when it got further in, this was another part of the shell It is very complicated Someone asked about the formula by which we calculate the average body temperature, on the assumption of a core and a shell I hope this calculation is never regarded as more than the next best approximation to using one temperature alone, being obviously the way you arbitrarily mix skin temperature and core temperature For the details of this calculation should really depend upon the type of individual you are working with (fat or thin) and whether he is in a cold or a warm place

But the fact remains, by adding to the calculation this mixture of core and surface temperatures, you achieve something much better than just using, say, core temperature But it is only a first approximation Since one should have an exact formula that was different for every individual and, perhaps, different from that individual in different circumstances, no formula would then be generally useful, would it?

Burch You cannot be arbitrary with this, it depends upon many circumstances

Irving With regard to your question about depth of the gradient, Edholm (27) has a few interesting figures of very deep and rather extensive gradients reported in some of his observations on the Channel swimmers I haven t considered the gradients in man First, I didn t know enough about the situation to bother about going through the work on myself or anyone else I haven t yet seen the situation in man when the gradient could be measured with any great significance, because of its small dimensions and our still extensive anatomic tainty as to what that situation is

However, I do think in those swimmers there is likelihood that the gradient would be sufficient so that even with our present lack of definition of the morphology of the shell and core, some useful observations could be made I think that is probably what you have in mind

Behnke The swimmer maintains his deep body temperature at about 38°C The skin temperature is 20°C The muscle temperature probably ... had temperature

... the blood flow to the skin What and what is the blood flow to the ...ge?

Burton If one takes the circulation of the finger as representing circulation of the skin, we have some information as to the range There is no muscle and very little bone flow in the finger The range of flow is simply enormous Of course, the range depends, if you are expressing it per 100 ml ... or last two or three ... ix, it changes from 0 5 ml/min/100 ... re than 100

... some interesting data on the terminal phalanx, by ...

the mean volume of flow for 5 gm of the finger ... it is for 5 gm of liver, 5 gm of brain, or 5 gm of left ventricle all tissues with supposedly high rates of mean flow, finger flow is five to six times as high as for the body as a whole

Burton This is maximum dilation?

Burch No, resting man in a comfortable environment

Carlson What temperature?

Burch The digital temperature would be about 31° or 32°C The renal flow, of course, is several times that for the digit In cold we noted flows too low to measure The question is, how long can such low flows exist before the ... phenomenon begins to develop and ... ise, flow is noted to rise ... pected If thermocouples are used ... ng started, the digital flow increased but not very much As Dr ... on said, it is quite variable, but fairly standard experimental conditions can be achieved if the experiments are carefully performed

Carlson The hand blood flow data in Dr Newburgh's (30) book would indicate the range isn't as great If you take the whole hand, the flow would probably be a matter of 20 per cent of this range

Burch I have studied his data Some of the measurements of flow,

with only mean flow as recorded in the literature, have large errors in them, because of some leakage and other phenomena as a decline in the A V pressure gradient Dr Burton and I argued about this more than once I think leakage is a large factor for the errors in venous occlusive plethysmography It is necessary to study the actual original recordings, if they are published, to evaluate the errors

Burton To return to the question of gradients, there is a small amount of data on how gradients may change, as between the white man and the Eskimo Malcolm Brown and Hatcher, in experiments already mentioned (31,32), got blisters in the Eskimos, and they also measured some muscular and subcutaneous temperatures There is quite a difference in the gradient in the Eskimo As I remember it, the muscle temperature is much higher than that found in the white, for the same skin temperature

Fremont-Smith If you watch the capillary flow in the nailbed in a person who is getting typhoid or malaria chill, it goes from the normal flow to a complete standstill where you can actually watch a corpuscle stop and remain stopped for a long time When the flow begins and, hence, the temperature is reaching the top, the shift may be very dramatic, within 20 minutes, from complete stoppage to capillary pul sation and the venous blood quite arterial So this is an infinite change from standstill to very rapid flow In the process of the change, you can see the individual capillary loops operate entirely independently of adjacent ones Therefore, the terminal arterioles must be separately innervated by the sympathetic, because I have watched this again and again You can see one loop flowing very rapidly, with adjacent loops on both sides at a standstill, and then they reverse themselves during this transition, from the complete vasoconstriction of the chill phase to the complete vasodilatation of the post chill phase I think this just bears out the fact that you got flows you couldn t measure in the tip and in the skin you can show it just isn t moving

Burch Another interesting observation we noted was that when flow was measured as the hand was cooled and as the hunting began, the basal flow, as I call it, declined practically to 0 When the vessels opened with hunting, fairly large pulsations developed, and the basal flow did not change very much In normal persons, the mean basal flow is about 12 ml per 5 ml of finger tip per second But as the tempera ture declines, it decreases to 2 or 3 ml, or less With hunting, it may remain at about 2 or 3 ml per 5 ml of part per second Apparently there is stasis to warm the tissue

Behnke To conclude what I say, I think we can get more data on actual measurements of blood flow to the skin in environments of 35°

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AVENUES OF HEAT LOSS AND PERIPHERAL CIRCULATION

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IT IS MY INTENTION to present an over all theory on which I would like to hang many of the phenomena of man s response to cold to cold adaptation and also to consider this theory in relation to the significance of cold injury and predisposition to cold injury

Figure 71 illustrates a single experiment that we did about a year ago in the laboratory It shows a hand-cooling experiment designed to demonstrate the hunting phenomenon we have just been discussing It demonstrates the hunting phenomenon in a given subject the experiment having been repeated a number of times in this same subject The conditions of the experiment were very carefully controlled The subject was allowed to rest to come to thermal equilibrium with the room environment in which he found himself The dotted lines represent the type of response that we usually got on this particular subject

Fremont Smith Where are you measuring?

Meehan We are measuring the temperature at the base of the nail bed of the index finger of the right hand with 32 gauge constant thermocouple attached with collodion and covered with one layer of adhesive plaster

The hand is immersed in ice water bath and carefully and uniformly stirred We maintained temperature in the immediate vicinity of the finger of approximately +¼°C above freezing This is the standard condition

The three responses of this individual represented by the dotted line show adequate and expected rewarming and cycling The solid line indicates [illegible] ature

Burc [illegible]

Meehan Yes This demonstrates the phenomenon that I had antici

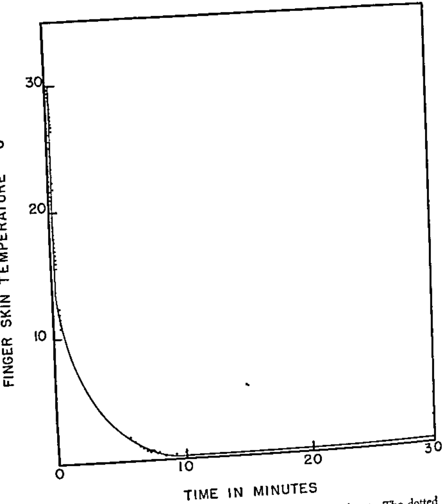

FIGURE 71 Four separate hand cooling experiments on one subject The dotted lines show the results of experiments conducted when the subject was in his normal subjective state The solid lines show an experiment conducted when the subject was in a state of marked anxiety

pated and had been looking for ways of demonstrating for some time I had seen a similar condition in two subjects here in Alaska when I was in service in this Laboratory The condition happened to have been in colored subjects This instance shown in Figure 71 happened to be in a Caucasian individual

The subjective response of the individual on the occasions indicated by the dotted line were about as would be expected by any of us who

are familiar with this type of experiment It is a painful experiment When the hand is removed from the water there is much pain until it rewarms However, after the rewarming, the unpleasant sensations from the hand disappear

After the experiment indicated by the black line, however, the subject had extreme pain in that hand He had extreme arthralgia That evening he required sedation in order to sleep He not only had arthralgia in the hand, but he had disturbed cutaneous sensations for 3 months after the experiment This man, then was a cold casualty to this experiment

I would like to fit this observation into the schema that we will give later As a way of introduction to this, at the Third Conference on Cold Injury Dr Malcolm Brown (1) presented his findings relative to the [illegible]

somebody else? Was he anxious? Was he nervous?

In reading the literature on response to cold we find this type of reference occurring rather frequently I believe that the central nervous system, as such, plays *the* major role in determining the individual's response to cold, whether this response concerns whole body cooling, whole body exposure, or local cold exposure This is the starting point of what I should like to discuss now I shall show a schema in which various parts of the central nervous system are represented These will be largely functional descriptions and anatomic locations will not be assigned in every case, however, I may suggest them where this seems appropriate Further this will have to be rather strictly limited to phenomena associated with cold It can be extended I am sure to other sensory phenomena However, for the purposes of the present discussion, and since time is limited, I should like to keep the area of attention here directed right at the peripheral sensations that are concerned with cold

The peripheral sensations that are concerned with cold and that play a part in an individual's reaction to cold are the temperature receptors for cold and the pain receptors These are represented by a block labeled 'receptors' in Figure 72 An arrow connects that block with another This block is called the central nervous system integrating areas It probably is from an anatomic standpoint, the cerebral cortex or, at least, a large part of it, so it might be called cortical integrating areas

Opposite this box is another that will represent the hypothalamic autonomic centers, and these boxes are connected by double ended

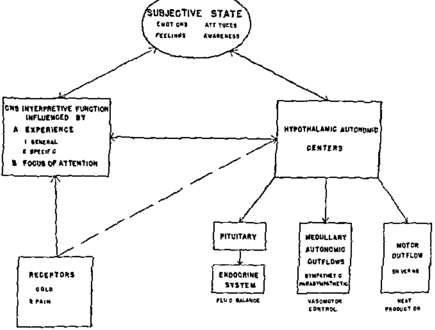

FIGURE 72 A functional schema of man's reactions to cold stress The dotted line represents an anatomic pathway, the functional significance of which is un determined in the presence of higher central nervous system activity

arrows Also interposed between these two boxes, instead of a square, is a rather oblong structure which indicates that this involves areas of the brain that cannot be described with too much accuracy at this time, anatomically, but we do know which functions are there This would have to do with those areas of the brain that determine the subjective state of the individual By subjective I mean what are normally spoken of as ideas the individual has, his emotional set, his emotional attitude, his feelings, etc , all these characteristics that determine the man s affect toward his environment

This structure is connected to both the cortical integrating areas and the hypothalamic autonomic areas by double-ended arrows An effector outflow for this schema is represented by three outflows The first will be communication to the pituitary gland and the endocrine system

Montgomery You mean the arrow is a communication by nerve?

Meehan This is a functional connection between the hypothalamus and the pituitary gland, and it is probably not nervous It involves the portal blood supply to that organ So, as I say, my representations are on a functional basis

The second outflow from the hypothalamus is the outflow to the medullary autonomic centers, called medullary autonomics From there, of course, we go to the various effector organs controlled by the auto nomic nervous system

The third outflow is relative to shivering Such outflows have been very nicely described in work supported by this Laboratory and work done by Dr Allen Hemingway* at the University of California in Los Angeles

As far as cold physiology is concerned these outflows will be con cerned as follows The pituitary and the endocrine system will certainly have effects on water balance and distribution in the individual

The medullary autonomic centers, of course, will have primary effects on the cardiovascular system The main response we talk about in cold physiology is vasoconstriction The outflows relative to shivering are perfectly obvious This, of course, gives us metabolic heat production

Burton I think many of us agree with you that there should be an arrow from the receptors directly to the hypothalamic centers, because we know with a decorticated animal, his temperature regulation may be disturbed Human operations on cortex give a kind of fever We do know a decorticated animal has a pretty good temperature regulation

Meehan Yes Spinal man has some temperature regulation too [illegible]

Burton Functionally, in decorticated animals the temperature regu lation is hardly disturbed This was shown way back Many of us feel [illegible]

ology, impulses have to go to the cortex whereas these experiments on decorticated animals suggest that, while there may be a pathway straight to the cortex (we have sensation, of course) the reflex mechanism oper ates directly through the autonomic centers, *not* via the cortex

Meehan I will compromise with your argument to this extent, in that I said cortical integrating areas, those areas are probably in the cortex I will also state that there are probably subcortical areas also involved, for which there is considerable evidence

Carlson I would like to make a plea for the arrow It doesn t destroy your argument Your other arrows would modify the response

Burton I think we know it

*Personal communication

Fremont Smith We don't know what his argument is Let's listen to his argument

Burch Are you explaining thermal regulation and the lack of hunting?

Meehan I am talking about the reactions of an individual exposed to cold

Burch What reaction?

Meehan The total physiologic reaction to cold exposure

Blair You can destroy in animals the line going from cold pain up to the cortical centers without disturbing temperature regulation, whereas if you destroy the arrow going over to the hypothalamic center temperature regulation is completely destroyed

Meehan Let me finish my argument Then, after that is done, I would like to enter into this type of discussion again That is the purpose of this presentation I want to stimulate discussion I also want to orient it along certain lines

Aside and apart from the arrow we have just been discussing, it may be that some of you may desire to draw other arrows on this diagram

Burton That is putting it very mildly

Meehan In other words, you have, as we all know, feedback mechanisms that connect the endocrine system with the central nervous system You may have several feedback mechanisms that could be indicated on this diagram

Travell Also feedbacks to the cold receptors?

Meehan Anything that is going to affect metabolism in general would probably affect the cold receptors, absolutely So, all of these things we must realize are interconnected This is a little bit idealized, however, it serves as a basis for the present discussion

I was interested in the response shown in Figure 71 because I had occasion to observe this sort of thing twice in people here in Alaska The absence of the hunting reaction has been related to an individual's susceptibility to cold injury, at least of the fingers

This individual, under one set of circumstances, had a perfectly fine rewarming reaction Under another set of circumstances the hunting reaction was entirely obliterated and he became, for practical purposes, a cold casualty

The difference in the two experiments was this The first three times the man was tested, he was calm and relaxed, and not at all apprehensive of the experiment However, the time when he failed to show rewarming, he had just completed an examination in which he had not performed very well, and he was very anxious about its outcome

Advantage was taken of this fact, and his fears were reinforced by

appropriate suggestions, and the experiment was carried forward This,

to a very standardized type of cold exposure

Fremont Smith This is very parallel to Wolff and Mittelmann s (2) work on patients suffering from Raynaud s disease where exactly the same thing was done and it was found that the patient could be thrown into a Raynaud s attack by anxious discussion or he could be thrown into a Raynaud s attack by lowering the temperature, but that if the temperature were lowered on an anxious day on the day after an examination, when he felt badly, it took much less lowering of the temperature to precipitate an acute attack of Raynaud s disease which could also be overcome by reassuring statements

Meehan Yes The thing to be learned from this type of observation is that the normal individual in his everyday life is going to have fluctuations in his subjective state I should like to propose that these fluctuations in his subjective state are really a part of his normal physiology and as such, are going to affect the response of any parts of the diagram I have drawn in Figure 72

The anxious individual is going to set a certain tempo for the autonomic activity in the hypothalamus which in turn is affected peripherally by disturbances and changes in the various sensory modalities presently considered It also affects the interpretive areas of the brain The individual becomes more sensitive to stimuli under some conditions, less sensitive under others

To carry this schema a little further, the cortical integrating areas function along at least two main points of reference The most important one is going to be the experience of the individual That experience can be general experience or it may be experience with a specific stimulus under a specific set of conditions

The other point of reference that this integrating system will use will be what I shall call the area of attentiveness or span of attentiveness of the individual By that, I should like to cite a common experience and I am sure most of you have had it If you are busily engaged on a project that is grossly interesting to you and you are devoting all your energies to it, you can injure yourself and be totally unaware of the injury until you observe it visually later You completely abolish the sensation of pain under these circumstances You have certainly stimulated the pain endings in the finger, the hand, or whatever has been injured but something has happened to prevent conscious recognition of the painful stimulus

Another point that brings reference to the discussion we had about the arrow leading from the receptors to the hypothalamus, I do believe that, generally, all peripheral stimuli that are received by the body, for practical purposes, are subject to interpretation

There is information relative to this, and I think probably some of the most pertinent data that bear on it are found in the information that has been derived on pain sensation and how it can be altered under the hypnotic state West, Neill, and Hardy (3) have done experiments in which they have measured the pain thresholds of subjects that have been hypnotized and have been given the suggestion that they have had anesthesia They have shown that the subject has complete anesthesia, that is, no conscious sensation of pain, there is no galvanic skin response to the painful stimulus This is one of the reasons I think we must say that these cortical integrating areas, cortex plus other areas, are going to affect functioning, at least the relationship between the peripherally disposed receptors and the hypothalamus

Carlson The relation between peripheral receptors and hypothalamus has been demonstrated The properties of the central nervous system which are involved here are changes in excitability, *i e*, facilitation or inhibition

Burton You perhaps, misunderstand None of us is doubting the tremendous influence of cortical control of autonomic centers, but doubt whether this is *essential* to the functioning of this regulatory autonomic mechanism We know that a decorticated animal does go on with this regulation, unmodified by his cortex On the other hand, if you cut the pathway directly to the hypothalamus, the regulation is absent This is absolutely essential to the whole mechanism, whereas your first arrow is not essential

Blair In addition to what Dr Burton says, with which I will agree under normal circumstances, there are two abnormal states that have nothing to do with the cortex in which curves can be produced that are identical in type to those shown in Figure 71 First, if a lowering of internal body temperatures is produced, hunting is blocked, just as shown in Figure 71 And second, even a minor degree of hemorrhage will produce the same effect They are not regulated by and do not produce any cortical effect that we are aware of

Meehan That is right Yoshimura and Iida (4) have done the most extensive study on the gross physiologic variables that affect the hunting Body heat balance is one, relationship to meals is another factor that will grossly affect it and, as you say, small hemorrhage changes in blood volume will affect it There are all of these many factors

Hildes Cooling the arm

Horvath The age of the subject

Blair Repeated exposure to cold

Meehan Repeated exposure only affected a small group of primitive people Yoshimura was able to study He tried the experiment in people, I presume, that were available to him in his laboratory By cold training dipping hands in cold water, and so on, he was not able to demonstrate any particularly significant modification, shall we say, of the hunting reaction

Burch Don t you think there are a lot of unknown factors that influence the hunting phenomenon? I am certain we do not know them all

Meehan I am sure we do, Dr Burch I am not denying the existence of local factors that probably affect the hunting reaction Apropos of the point of body heat balance affecting the reaction it certainly does On the other hand, you do not get this very painful and disabling experience in a given subject, every time he fails to rewarm

Blair But you get cold injury very quickly in the absence of the hunting response, as is shown in Figure 71

Burton I would like to question the interpretation of the results of Hardy that you report I don t have any direct conflict, experimentally, with Hardy s experiment, because, as you say he was measuring the psychogalvanic reaction I was measuring the vasomotor response of the blood vessels of the fingers, in a girl who had complete anesthesia of the forearm, not produced by hypnosis but a hysterical, psychiatric phenomenon To my astonishment, all of the autonomic vasomotor reflexes were there, even in exaggerated form, when you pricked the anesthetic arm

As to your general theory of temperature, I don t think the psychogalvanic reflex, which undoubtedly tells you the response of the peculiar sweat glands which are hooked up to the psychic system, (those psychically rather than thermally stimulated) is so relevant to what you are saying as is the vasomotor response In this girl, certainly, vasomotor responses were there, even though she had complete hysterical anesthesia

Fremont Smith May I support what Dr Burton is saying The emphasis is they were even in exaggerated form, because hypnosis or hysteria is a decortication, functionally The left upper block is out of function It is a quite well known fact that, under hypnosis and under psychosomatic conditions, where there is amnesia for the emotional conflict, the most exaggerated responses are obtained For instance, in the patients with Raynaud s disease that were being discussed, Wolff and Mittelmann, by talking to them, were bringing up disturbing, forgotten

factors, of which they had no memory, which were the most potent in precipitating the Raynaud s attack

I think that the psychogalvanic does seem to be very difficult to bring in, and that the inhibition of the cortical control of the autonomic by hypnosis, hysteria, or what takes place, of a similar nature, under neurosis, so to speak, is of great significance, because there are the exaggerated responses which will, I would think, lead to injury

Meehan I have worked with Dr Hardy on one of his projects here He is a very thorough investigator I might say he has also experimented with hysterical anesthesia, and the psychogalvanic skin response was this in hysterical anesthesia In other words, if you painfully stimulate the anesthetized limb, you still get the psychogalvanic skin response

Fremont Smith Only in his particular hypnotic experiment

Meehan It was only in this

Burton He did not test the vasomotor responses in hypnosis?

Meehan You can t

Burch The psychogalvanic method is relatively insensitive from the point of view of vasomotor response, as Dr Burton said I should like to point out that the vessels of a fingertip are very sensitive to psycho logic disturbances

Meehan You are absolutely right In defense of this hysterical anesthesia the psychogalvanic skin response does remain and, as a matter of fact, it can be exaggerated

Carlson I hope Dr Burch will document his assertion that a finger tip is much more sensitive than the GSR to psychomotor disturbances

Meehan There are experimental ways of getting at these various mechanisms that take place One of the methods I have tried in the last 3 months is the application of hypnosis to see what can be done about modifying these responses We have done experiments both in local hand cooling and the type I have described here and, also, on whole body cooling

While I am no expert on the matter of hypnosis and do not pretend to be, some point should be made about the hypnotic state An individ ual injuring his hand and not being aware of it, when he is focusing all of his energies on some task, is an example of the hypnotic like state

Another example of a hypnotic like state is the so-called driver hyp nosis that apparently is a problem now on our long relatively straight highways drivers follow the white line down the road, and lose certain contact with their surroundings They can be involved in very serious accidents

These things, perhaps, are not true hyponotism or true hypnosis but they are situations that are similar Hypnosis itself, then, simply involves

narrowing the span of attentiveness of the individual to very few or to only directed peripheral stimuli In other words, when you hypnotize [illegible] very small things, [illegible] hear something, he is not going to see something, he is not going to feel something, except certain experiences that you want him to have Also, the hypno tized subject is conscious If a person is hypnotized, you do something to him Have him wake up and he can tell you exactly what happened He has no loss of memory for the event

Fremont Smith Unless you tell him to have it

Meehan Yes If a person is satisfactorily hypnotized, you can talk to him, you can have him open his eyes, look around and see things or do whatever you wish The extremes, of course are the situations that the stage hypnotist tries to get hold of for demonstrations in front of an audience

Hypnosis as an experimental tool can be used to modify the func tional interrelations between the various parts of the central nervous system involved in man s response to cold

Other points that should be kept in mind are Even the hypnotized subject will interpret your suggestions on the basis of his past experi ences For example I had a subject in a cold room and I told him it was getting very cold, when it wasn t I described all of the sensations that he should experience very well, and nothing happened He came out of the trance This man had lived in North Dakota and had had considerable experience in being out in the cold, and he knew that, when [illegible] pass [illegible] cons [illegible] notic [illegible] ing it entirely, you are just narrowing it down

Another factor that should be kept in mind when working in this field is that in addition to the specific stimulus or the specific suggestion given the individual, it is necessary also to know what the content of the suggestion is going to be, as far as the subject is concerned For example, you could suggest anesthesia in an individual and get one response If you get complete anesthesia, of course, you will get the effects described by Dr Hardy (3)

You could also tell the individual, Well, now, something may feel a bit uncomfortable, that is, it may hurt or may feel cold or may feel hot, but it isn t going to disturb you You will not be disturbed by this experience You will remain comfortable during this experience

The other thing, of course is you can tell him, ' Now, it is going to hurt like the very dickens and see what happens

I would like to restate that I consider that hypnosis is only a tool by which the behavior of the central nervous system can be modified in an experimental way I don t know yet, but I hope that it is a tool that can be applied in a fairly reproducible way, so that these experiments can be repeated and confirmed

In giving this information I certainly do not deny the effects of local control, the local effects of temperature on the body My thesis is that the body s first reactions to peripheral stimuli are going to be mediated through the central nervous system, and that the central nervous system will maintain very extensive control on the autonomic system over quite a range of circumstances

As you know, this particular hand cooling experiment is a rather painful experience If you want to have subjects repeat for you, some times you have to do a pretty good selling job in order to encourage them to stay with an experimental program of this kind (Figure 73)

I might say that another practical use of hypnosis I found in doing these experiments is that at the very end of the experiment a man can be hypnotized and told he is going to forget all about it, and he won t be bothered by it, he won t remember the experiment, and will come back indefinitely The experiment indicated by the solid line is one that was done on a man both times he was hypnotized The thermocouples are placed as I had previously described The upper lines indicate the response of thermocouples on the contralateral hand Those are actually a pair of thermocouples parallel together, placed on the index and third fingers The solid lines represent one experiment and the dotted lines another

He got a very nice rewarming reaction, as is evident The contra lateral finger temperature first dropped and then actually rose That is a matter of around a 4 degree rise in the contralateral hand, after the initial drop in temperature

Travell How long is the period in minutes?

Meehan The whole period is about 28 minutes in time

Hildes Of immersion?

Meehan Yes In the dotted line, the suggestion was modified a bit He was told that the situation would be very disturbing to him and would be unpleasant This time he showed rewarming all right, but it

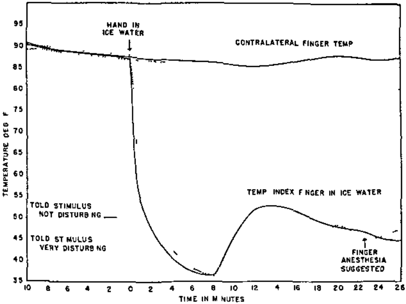

FIGURE 73 Two hand cooling experiments performed on the same subject using hypnosis to demonstrate the role of cortical interpretation in determining the peripheral physiologic response to cold exposure

was of a different pattern The opposite hand showed continued vaso constriction as the skin temperature continued to fall throughout the entire course of the experiment

Burch What was the time interval between the two experiments?

Meehan A matter of a week, perhaps

Fremont Smith Where would the room temperature be with respect to this fall in the contralateral hand?

Meehan The room temperature would be between 82° and 83°F

Fremont Smith In other words, the contralateral hand came down to room temperature, practically

Meehan This actually is probably a little below I have my raw data plotted, I can check on it, but it is probably about that

Fremont Smith This is what you expect, it came right down to room temperature?

Meehan Yes

Fremont Smith Unless you say room temperature, you don t know how much the contralateral hand seemed to move

Meehan That is right

Burton May I ask how consistent the curve would be, if you sug ested it wouldn't hurt him, under the same conditions?

Meehan It will follow that curve quite closely under identical onditions

Burton You have repeated just the first type of suggestion and it ave very much the same curve as the black line?

Meehan Yes

in the

experi ment

Fremont Smith It could be done

Meehan It could be done, certainly The abilities in subjects are reat Their imagination can run wild on the type of experiment you vant to do

Going back to my diagram, this objective state, again, will react to letermine the individual s interpretation of the stimulus It also acts o affect the level of activity of the autonomic centers of the central ervous system, whatever they may be

Hildes Have you some idea as to how painful each of these are to im at the time?

Meehan Let me come back to that again, in a minute There is one nore point on there I want to bring out An unpleasant sensation can voke emotional response in a person, of itself if that sensation has ome previous association with unpleasantness to that individual In ther words, it depends on his previous experience

I think this is digressing a bit to more general terms This is the area hat is going to have a lot to do with how an individual is going to react to an unusual situation or an unusual environment

His experience, either with the environment or with related experi ences, or with situations that have similarity to the new one will very remarkably affect his response to that environmental exposure The

over all

This is why, if people are going into unusual environments, the matter of training is extremely important We all know that our experiences under a given set of circumstances are pleasant, and we like them We can go back to that circumstance, we like it We get along very well I think that our physiologic behavior is similarly affected So that, if we can enter an environment that we have found to be pleasant, or we

Fremont Smith He started to rewarm, when you suggested anesthesia?

Meehan That is right

Fremont Smith You removed from him the interpretation that it was cold

Meehan There wasn t any response in the contralateral hand, however

Hildes Maybe that is just another cycle

Burch Are you sure that is unusual?

Meehan What is unusual?

Burch The rate of rewarming

Meehan In the light of the experiment yes indeed

Burton Don t you usually find the second cycle? If you have hypnosis or not and don t do anything to the subjects you usually find after that length of time, you start a second cycle?

Meehan We started one

Burton In what way is the rise distinguishable from another cycle that happens to occur?

Meehan It is a sharper rise, from my own experience, than I would expect

Montgomery This experiment was performed a number of times?

Meehan Yes

Fremont Smith If it were carried a little further or if you were to introduce the suggestion of anesthesia at different intervals—you always got the sharp rise within a few minutes after this suggestion—you would prove your point, wouldn t you?

Meehan That is right I have not done very many of these experiments yet This is a point that we observed in this particular experiment

Irving Might it be of advantage to utilize the terminology which developed in connection with the spinal reflexes and with conditioned reflexes which, irrespective of whether or not the same central mechanisms are involved at least permit ways for describing in sort of quantitative if arbitrary and familiar terminology, what the reactions are in relation to the stimulus how the stimulus is based, and certain other circumstantial conditions as well

Blair I should like to see you resolve this question by possibly another method, Dr Meehan, and that is this If you will immerse the foot and the hand in cold water, you will produce the hunting reaction in both, but not in *same cycle or rhythm* But if you produce through hypnosis a rise in temperature of the hand and foot, it should be simultaneous and follow the same pattern

Meehan You have to be very careful of experimental work of this

type The technique of hypnosis is not simple I happen to be doing it in our own laboratory, and I know that to do an experiment like this requires my devoted attention for quite a period of time Though your production of data is not as rapid as your enthusiasm would like it to be, at least that is my problem so far

So far I have talked about the effect of the local reactions to cold I have given a rather startling example of the effect of a very marked change in subjective state on the response to the hand-cooling experiment I think that example is important I think it should always be borne in mind that a person exposed to cold can experience this reaction If he does, he might be in considerable difficulty

I can go on now and discuss some experiments we have done on whole body cooling along the same general line

Fremont Smith The opposite of being in an unhappy state is the condition of high morale So that this relates directly to the military, in the sense you are trying to avoid, for people who are going to be exposed to cold, the condition which would lead them to this injury The converse of that is you would like them to have a high morale Is that right?

Meehan Absolutely right This is very, very important, I think

Fremont Smith I wanted to put it in a military context

Burch Our studies have shown it makes a great difference as to the state of mind as we call it of the patient

Meehan This applies very specifically to the military situation I think it has more general implication in that it applies to our everyday life activities If you want to extend this type of discussion further, you can, to include other peripheral stimuli and other types of reactions As I say we limit it here to the considerations at hand

You can also, by whole body cooling examine the shivering response which is particularly interesting As you know, hypnosis has been used or is used in anesthesia by some people I do not know to what extent all over the country In Los Angeles, we have one very capable anesthetist that uses hypnosis in difficult surgical cases, and has used hypnosis as the form of anesthesia in cardiac surgery, and in cardiac surgery in which hypothermia is used

Fremont Smith A cesarean section was done recently in Chicago under hypnosis with no other anesthesia

Meehan That is right

Fremont Smith It was reported in the newspapers

Meehan I have had some experience, as a result of getting started in this work in applying hypnosis in minor surgical procedures and even in some major procedures I think hypothermia would be of inter

est to this group at the present time I am not aware of anyone report ing the matter of being able to drop a subject s internal temperature on cold exposure significantly by hypnotic suggestion I have looked around through the literature to try to find information on this

Beaters It can be done with a suggestion of hallucination of an experience which would ordinarily drop the temperature It has been done (5)

Meehan I have tried it I suspect that it would be a rather difficult thing to induce generally and it could probably be done only on certain subjects Unfortunately the ability to use a subject under hypnosis is a matter of individual variation again and not every person is capable of the same depth or type of hypnosis So that I suspect you might not find the individual that you could actually use as a subject

In our own experience I found if we put a person in the cold room starting out at ambient temperature of about 95°F or between 85° and 95°F it doesn t much matter If we cool him steadily down to average temperature of 40°F the following can be done by hypnotic sugges tion A rise in rectal temperature very frequently seen on whole body cooling can be prevented in experiments of this type or conversely it can be reinforced or exaggerated

Also considerable control can be exercised over shivering Here again the type of suggestion that is used is subject to considerable in terpretation A suggestion must be used that is acceptable to the indi vidual We did one experiment on a man in which he was told that he was going to be given a particular vaccine that would cause him to have a very high fever This is a technique that is not original but it has been used He was hypnotized and was given an injection of vaccine and was told during the control period that his body temperature was rising

Fremont Smith He was injected with real vaccine?

Meehan No

Fremont Smith The whole thing was hypnotic?

Meehan That is right

Fremont Smith You said he was given the vaccine but you didn t indicate by suggestion

Meehan He was told he was getting very warm He did not show any vasomotor adjustments in response to these suggestions however We started to cool the room His rectal temperature stayed fairly con stant His peripheral temperature started to fall in about the usual pattern for this subject

After the experiment had been carried on for about 30 minutes I told him he was going to have a real shaking chill which he did Then I

was disappointed I had him all arranged to take his metabolic rate, and he shook so violently the mouthpiece came out and I lost that piece of data He shivered very violently for approximately 6 to 8 minutes

The interesting thing is that the shivering was followed very promptly by a rise in rectal temperature of about 1° or $1\frac{1}{2}$°F The trunk temperature ceased to fall and started to rise The face temperature stopped falling and proceeded to rise The extremities temperature, on the other hand continued to fall at about the same rate as before the suggestion of shivering

Montgomery There was no rise in body temperature before the shivering?

Meehan No

Fremont Smith You gave him the wrong suggestion People coming down with fever don t feel warm they feel cold If you told him he was going to feel cold, you might have gotten the rise in body temperature You didn t give him a physiologic suggestion However, perhaps you did not intend to

Meehan

to react to th

couples paste

some length with the subjects and get enough of their background so I could use suggestions that would be acceptable This particular subject was interested in going to medical school and had a considerable body of information pertaining to medicine, some of it erroneous Anyhow, I found I had to fit into his knowledge and how he interpreted these things If I did that I came out all right But it is a demonstration, again of how even under hypnosis the subject is going to interpret the suggestions you give him

Burton I wonder whether this shivering as you call it, had anything like the pattern of reflex shivering Dr Eugene F DuBois * many years ago had a subject that tried to imitate shivering, and he found that the oxygen consumption didn t go up nearly as much as it did with natural reflex shivering In other words, I think by this suggestion he was making himself shake subconsciously, but this really isn t like the pattern of activity of the muscle that one has in real shivering

Meehan He shivered for 6 minutes When I terminated the experiment he was blue and I thought I had better let well enough be I gave him the post hypnotic suggestion of amnesia He said Gee I feel fine but my muscles feel like I had been working

Fremont Smith An electromyograph would have shown if these were voluntary I think you are right they were voluntary

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*DuBois E F Personal communication

Meehan Very likely they were I found in general under hypnosis it is one thing to tell a subject that the situation is going to be entirely different from what it actually is and it is quite something else again to tell him the situation is going to be exaggerated one way or the other It is relatively easy to exaggerate the situation it is hard to

to feel warm

ery very mild

ıan around 25

to 50 per cent by this type of activity I hope to be able to get metabolic rate measurements under these circumstances However I have a prac tical problem of collecting the gas sample from the subject On the other hand you can tell the individual Now it is getting very cold in here when it actually is getting cold and get a very exaggerated response Conversely you can tell him Now it is getting warmer in here and warm the room by ½°F and completely inhibit shivering He may have been shivering violently be opisthotonic and if you tell him It is warmer in here at that same moment if you warm your room the slightest amount shivering will stop dead even though the amb ent

My experience to date is if you continue this for around 15 or 20 minutes you see the recurrence of a little shivering again in spite of the fact that you told them the room was getting a little warmer So that the abilities in this direction do seem to be limited

In the application of hypnosis or anesthesia to be used in hypother mia I find most anesthetists do use the curare derivatives to inhibit the shivering during the cooling phase However the amounts of drug required are relatively quite small Once the individual is cooled down to an internal temperature of around 32°C no further medication is needed and the individual can be carried for several hours under these circumstances

Beavers Is the hypnotic state still in effect at 32°C and below?

Meehan It certainly is

Cotino What do you think the advantage of hypnosis in hypothermia is?

Meehan As surgical anesthesia?

Cotino Yes

Meehan The advantage is you don t have to give the patient chemical anesthesia It is a great advantage as anyone will appreciate who has to deal with practical surgical care

Beavers Do you distinguish between the effects of cold *per se* in

the hypnotic state? Doesn t a person at 32°C have a sort of hypnotic state? I believe Dr Talbott (6) described such behavior many years ago The description of individuals at these low temperatures, without much anesthesia, seems to be very similar to a hypnotic state

Meehan Except that people still respond to suggestion In other words you can have them open their eyes and look at you, or talk to them

Talbott We are concerned with psychiatric patients who were, profoundly affected Our studies were not carried out upon normal subjects

Behnke Can you give a drug which suppresses shivering and then have the patient, under hypnosis, shiver?

Meehan I don t know, I have not tried this

Fremont-Smith I can report one experiment that bears on your thing G R Heyer (7) reported an experiment which had been repeated many times *i e* that a patient under hypnosis was given a cathartic which in reality was a large dose of opium, or a constipating drug, in reality, *e g*, castor oil, and immediately not the medicament, but the suggestion, took effect

I think that your experiments go in this direction that they don t go to reversal but will modify or diminish a physiologic effect, and therefore, you would expect them to modify or diminish and conceivably reverse a pharmacodynamic effect, because those also operate through the physiology

Carlson With the exception if you choose your drug to operate at the nerve endings, you expect to have a difference

Fremont Smith Yes this would make a real distinction I don t know of any data on that

Burch Are you suggesting that hypnosis is more reliable than drugs in the production of hypothermia? This is true only if you have a good subject is that what you mean?

Meehan Yes The chances of getting good results are a lot better if you can use hypnoanesthesia

Burch For the average patient, who must have hypothermia are drugs more dependable?

Meehan I will avoid answering your question directly More study of the phenomenon of hypnosis is needed

Burch I mean at the present time

Meehan Let me follow through a minute You are going to find you can pick up and do under hypnoanesthesia a greater percentage of subjects than now are generally done

Fremont Smith Isn t it possible to pretest the patient for hypnosis? You do this so you wouldn t start an operation under the first hypnosis

but find you have to find it three or four times and find the patient was going to respond Am I right?

Meehan That is right You can t hit the individual

Fremont Smith So you can separate the sheep from the goats in

of the 100 would

he percentage of people you can get at by using minimal barbiturate sedation prior to induction of hypnosis Barbiturates seem to increase the suggestibility of a person in small dosages This is a very useful adjunct

Talbott Is the percentage of susceptible individuals 1 in 20?

Fremont Smith I don t know what it is I know a number of studies

other than testing for hypnosis itself There may be something you know that I don t know

Meehan There are certain tests of suggestibility that can be performed these will give you a rough idea

Fremont Smith Are they really reliable?

Meehan Not really In my experience they are about 80 per cent good They give a fair amount of insight They are all tests based on suggestibility

Fremont Smith About how many in 100 people would you expect could be hypnotized? Have you any idea?

Meehan My own experience is too narrow on a subject group to say I have actually been able to hypnotize nine out of ten people

Talbott By random selection?

Meehan Yes but remember these people are volunteer subjects for an experiment so that they are rather well motivated and selected before I get them On the other hand if I used straight population I don t know where I would be

Burch When you say suggestible do you mean the subject is cooperative or suggestible?

Fremont Smith He didn t ask him to hold out his hand

Burch I would consider him a very cooperative fellow

Fremont Smith This was anticipatory

Burch I wondered about the terminology

Burton To get back to hypothermia anesthetics are used in hypothermia not merely to anesthetize for pain but to break through the defenses against cold so that it is easier to get them cold

If you suggest you have hypnotic anesthesia do you find that there

is any inhibition of this defense against cold? Is it not more difficult to get the temperature down than if you use the ordinary chemical anesthetic? Do you also suggest to them they are not going to shiver and so on?

Meehan I just suggest anesthesia

Burton That automatically seems to depress the defense against cold?

Meehan It is necessary to use some one of the drugs that will block shivering usually one of the curare derivatives

Burton You are using that in addition?

Meehan Of course that works way out at the end of the scheme

Montgomery Shivering isn t blocked with hypnosis

Meehan That is the point It cannot be blocked entirely

Fremont Smith You said you could diminish

Meehan It can be modified diminished it can be exaggerated but it can t be blocked

Carlson The drugs are potent vasodilators so the subject cools rapidly I wonder if your subjects cool any more slowly

Meehan Cooling rates are all just about the same

Fremont Smith Isn t the vasoconstriction of exposure to cold inhibited because they don t feel cold because you suggested anesthesia? Therefore they remain vasodilated just the way the drug would make them vasodilated

Burton I still have reservations about whether you should say you *are able to modify shivering If there were only some way we could* [illegible] sug [illegible] we

It seems to me until we know that we are not right in calling this shivering It might be coming down the pyramidal tract True shivering is an autonomic activity and it doesn t come down the pyramidal tract at all

Meehan That is absolutely right I have no direct evidence one way or the other that I can show you I have observed these people myself in the cold room rather carefully I know the appearance of the shivering is quite shivery It does not impress me We have done experiments with voluntary shivering and that sort of thing I know about what the appearance of this type of shivering would be

Fremont Smith Would electromyograph distinguish these two Dr Burton?

Burton I heard someone say they are beginning to pick up action currents from the cord of the entire man The electromyograph in the

suggestion itself, which is the feature of hypnosis, we are always going to be in a little bit of dilemma whether the person is hypnotized or not

I remember a very experienced hypnotist demonstrating a case of retrospective memory to me, of reverting to an earlier age The subject was a girl and she put on a demonstration which was certainly a most *dramatic thing I was overwhelmed by her*, a 20 year old, talking with the voice of a 12 year old and describing her birthday at 12, etc About 3 weeks later I received a letter from the hypnotist saying she was sorry to say that after studying the case quite carefully, they could not make up their minds whether the patient had been under hypnosis or not

Meehan This is a real problem I have an experiment that sort of demonstrates that when you are making measurements of the autonomic activity of a person you can sometimes get some fair idea of what might be occurring

I have been able to hypnotize a fair percentage of subjects but I can t hypnotize everyone I have a record of a man that I can t hypnotize although he would like very much to be

Fremont Smith So he says

Meehan Yes, so he says This is what he tells me On the other hand he is quite suggestible in the waking state So, on one occasion we did an experiment on him, just to get his average response to an experiment of this type

We find for example, that he will ordinarily not show any rise in internal temperature *and I know about when to expect to have him shiver*, and so on On one occasion which is shown in Figure 73, we tried to hypnotize him This dotted line represents the finger temperatures of one hand

Immediately when I started to try to induce him, he showed peripheral vasoconstriction and finger temperature *started to drop before* the cold room was turned on When the cold room was turned on he showed a rise in rectal temperature of about 2°F

Talbott Has he been exposed to another hypnotist?

Meehan No

Talbott Are you the only one that is responsible for these studies?

Meehan Yes

Fremont Smith This could have been an anxiety reaction over whether he would be hypnotized or not

Meehan That is right *My observation is of that sort In an experi*ment, a subject can go along with a gag I gave him suggestions of shivering, and so on, and it was apparent he was just being cooperative Shivering was obviously put on

Fremont Smith By and large, you really don t have much trouble

with your own subjects do you in being quite convinced as to whether they are hypnotized or not?

Meehan No I don t

Hock There is an old book by a man named James Braid (10) who appears to have been the founder of a school called Neurypnology entitled Observations on Trances or Human Hibernation It seems that he found hypnosis induced a drop in temperature

Fremont Smith Some observations of psychologic shock among natives have been reported These primitive individuals even have gone to the point of death when they believed they had been bewitched This is obviously in this same category

I think there are instances where the suggestion reinforces something which perhaps has a physiologic basis and in which very profound disturbances can be observed

Dr Talbott you and Dr Stanley Cobb (11) studied a woman with hysteria at the Massachusetts General Hospital who hyperventilated to excess did you *not*?

Talbott She had profound changes as far as the internal environment I apologize for the use of the word profound

blood are reported

…gomery

Talbott She s …nosis

Fremont Smith … related suggestion which is what hysteria is will produce under certain circumstances very profound physiologic changes So that this reference made by Dr Hock to the possibility of a man possibly throwing certain selected persons into a hypothermia situation seems to me not to be dismissed it is still within the realm of our physiologic potentialities

Behnke It is said that the elderly Samoans are able to induce a resignation type of death They just go out and die

Travell Do they stop eating?

Montgomery They stop drinking

Travell Stop both eating and drinking?

Behnke I don t think it is a starvation death but they don t eat very much

Fremont Smith They die sooner than they would from starvation in 24 hours

Montgomery That is an example of self hypnosis? How is self hypnosis stopped?

Meehan Actually I think a lot of these factors including the prac

tices of the yogis, are forms of self hypnosis As far as I know and

to get out of the trance, once you are in it

An individual can be put in a trance and go to sleeep I have seen this done in certain cases of anxiety, for example An individual can

time spontaneously wake up, sometimes a matter of a few minutes or it might be a matter of 2 or 3 hours, or perhaps a bit longer

Montgomery That person wanted to wake up, that person had de cided he was to wake up?

Meehan If you hypnotize somebody and say, ' I am going to go away for a while, he will stay there and probably go to sleep Then he will wake up from that sleep

In doing hypnotic experiments, one pitfall that is even greater than worrying about whether or not the subject is actually hypnotized, is his tendency to go to sleep In establishing the hypnotic state you use sug gestions perhaps of comfort, relaxation and so on You may get the individual so comfortable and relaxed that he will go right to sleep Once he has done that, he is no longer hypnotized The hypnotic state is not like the sleep state From information available on electro encephalograph, it is like the waking state, not like the sleep state (12)

Rodahl I heard of two Eskimos in Gambell who convinced them selves that they were going to die, and they died

Talbott Were they young or old?

Rodahl One was fairly young and the other was old

Fremont Smith Do you know how long it took them to die, and what happened?

Rodahl I believe it took a matter of months They faded away Everyone in the village knew this was to happen They sat in bed, they just didn t eat

Travell Have you made any measure of the histamine response in these patients? Irving S Cooper (13) has shown that the triple flare after histamine is normal in hysteria The histamine response is sup posed to depend on axon reflexes but, actually, he has shown that it is considerably modified by interruption of certain central pathways

Meehan There is literature on this subject as there is on blister formation, and so on, under hypnosis I looked over a fair amount of this material Unfortunately, the reports have not been examined in detail or very well described, and unless I had repeated the experiment myself I would hold it in doubt

Travell The histamine response might be a very simple indicator of the vasomotor state

Meehan Yes it might

Carlson Incorporating the concept of the reticular formation and its thalamocortical projections adds considerably to Dr Meehan s diagram

Meehan I should like to summarize the points I leave with you as a result of this discussion I believe that the body s first defenses first reactions to stimuli, peripherally applied are through the central nervous system and that they follow functional pathways roughly as indicated in Figure 72

I feel that the response of the individual can be very greatly modified by this interpretive function that I have assigned to the central nervous system I also feel that this can be a very very important part of the

individual, and this likewise is very important It can greatly modify physiologic responses to applied standardized physiologic stimuli

The outflows that I have indicated here are, perhaps, only roughly accurate, but they indicate that the central nervous system has a very remarkable and profound chance of controlling the whole of our body physiology

Burch Don t you think the term autonomic has been taken too literally in many of the discussions in the past?

carefully avoided doing that I wanted to keep the discussion more in the realm of physiology I think it belongs there

Fremont Smith So do I, and I want to tell you how much this is appreciated It is confusing to others when men in a specialty use language that is peculiar to that specialty It was rather interesting that

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